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CIRCULAR OF THE DEPARTMENTS OF

MATHEMATICS, ASTRONOMY AND ASTROPHYSICS, PHYSICS CHEMISTRY

PUBLISHED BY THE UNIVERSITY
1908

GENERAL INFORMATION

The Organization of the University includes: the Graduate School of Arts and Literature; the Ogden (Graduate) School of Science; the Colleges (Senior, last two years; and Junior, first two years) of Arts, Literature, and Science; the Divinity School, the Law School, Courses in Medicine, the College of Education, the College of Commerce and Administration; the College of Religious and Social Science.

Faculty, Endowment, and Equipment.—The faculty numbers three hundred and seventy-six; the libraries contain 470,856 volumes. The University owns ninety acres of land (valued at $4,231,977) in Chicago; has thirty-one buildings which cost $3,912,861; and holds productive funds to the amount of $12,526,566. The annual expenditures are $1,304,417.

Location of the University.—The University grounds lie on both sides (all buildings on the north side) of the Midway Plaisance between Washington and Jackson Parks, six miles south of the center of Chicago. Electric cars, elevated trains, and the Illinois Central suburban service reach all railway stations.

The University Year is divided into quarters: the Autumn (October to December); the Winter (January to March); the Spring (April to Mid. June); the Summer (Mid. June to August). For the year 1908-9 the exact dates for the opening of the four quarters are: Summer Quarter, June 13, 1908; Autumn Quarter, October 1; Winter Quarter, January 4, 1909; Spring Quarter, March 29. Students are admitted at the opening of each quarter; graduation exercises are held at the close of each quarter.

The Unit of Work and of Credit is a *major*, i. e., a course of instruction involving four or five recitations or lecture hours per week for a full quarter, or double that number of hours for a term of six weeks. A *minor* is one-half a major. Normal work is three majors per quarter, or nine per year of three quarters.

Degrees.—The Graduate Schools confer the degrees of Doctor of Philosophy and of Master of Arts, of Science, and of Philosophy; the Colleges, the degrees of Bachelor of Arts, of Science, of Philosophy; the Divinity School, the degrees of Bachelor of Divinity, Master of Arts, and Doctor of Philosophy; the Law School, the Degrees of Doctor of Law and Bachelor of Laws; the School of Education, the Bachelor of Education.

Tuition, Fees, etc.—The regular fee for three majors in Arts, Literature, and Science, and in the College of Education is $40 per quarter. All students pay once a matriculation fee of $5. In Law and Medicine, the fees are $50 and $60, respectively. Laboratory fees vary from $2.50 to $5 per major per quarter.

Cost of Living.—In University dormitories, rooms rent from $18 to $66 per quarter. Table board in the woman's halls from June 13, 1908, will be $4.50 per week. At Hutchinson Hall (à la carte service) board costs from $3.50 per week upward. Board and lodging may be had at the same or even lower rates outside the University.

Fellowships, Scholarships, Student Service, etc.—By virtue of endowments and special appropriations, fellowships and scholarships and service afford stipends or tuition to a number of able and deserving students.

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MATHEMATICS, ASTRONOMY AND ASTROPHYSICS, PHYSICS, AND CHEMISTRY

FACILITIES

The equipment of each department will be referred to in the pages which follow, but it may be said for all, that the equipment is adequate for effective instruction and research in all lines in which work is offered. The Departmental Libraries contain files of the more important periodicals relating to these sciences, and most of the treatises and special publications necessary for research work.

DEGREES

Graduate study may lead to the degree of Master of Arts, of Philosophy or of Science, or to the degree of Doctor of Philosophy under the conditions specified below.

I. THE MASTER'S DEGREES

1. *Candidacy.*—Any member of the Graduate Schools who has been in attendance one quarter or more, and whose undergraduate course is equivalent to that required for a corresponding Bachelor's degree in the University of Chicago[1] may, on recommendation by the department or departments in which he is working, be enrolled by vote of the Faculties of the Graduate Schools as a candidate for a Master's degree. Admission to candidacy must precede the conferring of the degree, by at least two months.

2. *Requirements.*—Students thus accepted as candidates will be given a Master's degree on fulfillment of the following requirements:

a) At least three quarters' residence at the University.

b) At least eight majors of graduate work. These eight majors need not be all in one department, but must be selected according to some rational plan, approved by the Dean of the Ogden (Graduate) School six months before the degree is conferred. The individual courses must receive the approval of the heads of the departments concerned.

c) A satisfactory dissertation on a subject approved by one of the departments in which the work is done.[2]

d) The delivery of five printed or typewritten copies, including one bound copy, of the dissertation to the University Library, three weeks before the Convocation at which the degree is to be conferred.

e) A satisfactory examination on the work taken for the degree.

[1] In case the candidate did not obtain his Bachelor's degree at the University of Chicago, he will present to the University Examiner, on a blank furnished for the purpose, a detailed statement of his undergraduate work.

[2] In exceptional cases, the Dean, upon the recommendation of the department concerned, may accept an additional major in lieu of the dissertation.

II. THE DEGREE OF DOCTOR OF PHILOSOPHY

The degree of Doctor of Philosophy is given, not on the basis of the completion of a certain amount of time spent upon a specified programme, but in recognition of high attainments and ability in the candidate's chosen field, as shown (1) by the production of a thesis evincing the power of independent investigation and forming an actual contribution to existing knowledge; and (2) by the passing of examinations covering the general field of the candidate's studies, with more minuteness in the case of the principal subject, and with less minuteness in the case of the secondary subject or subjects.

1. *Candidacy.*—Any member of the Graduate Schools who has been in attendance one quarter or more, whose undergraduate course is equivalent to that required for a Bachelor's degree in the University of Chicago,[1] whose thesis subject has been accepted by the principal department, and who has a reading knowledge of French and German (which must be certified by those departments) may, on recommendation by the principal department in which he wishes to take his degree, be enrolled, by vote of the Faculties of the Graduate Schools, as a candidate for the Doctor's degree. Admission to candidacy must precede the conferring of the degree by at least two months.

The attention of students is particularly called to the fact that the examination in French and German must be passed before admission to candidacy for the Doctor's degree. It is important that the student should be able to read these subjects early in his university course. To postpone any work necessary for this examination till late in the course is to fail in securing the advantages intended by the regulation.

2. *Requirements.*—Students accepted as candidates will be given the Doctor's degree, on the fulfillment of the following requirements:

a) At least three years of resident work at the University, in pursuance of an accepted course of study. The course in question must include one principal subject, and either one or two secondary subjects. The amount of work required in the secondary subject or subjects is nine majors. Candidates should arrange their work as early as possible with the heads of the departments in which their major and minor subjects are taken.

b) A satisfactory final examination upon the work done in preparation for the degree.

c) The presentation of a satisfactory printed thesis upon a subject which has been approved by the head of the department in which the principal part of the candidate's work has been done.

d) A good command of literary expression, and such knowledge of subjects considered fundamental, as may be prescribed by the several departments.

e) Candidates for the degree of Doctor of Philosophy may not, as a rule, take more than two-thirds of their work in one department, and may not take work which is to count toward the degree in more than three departments.

[1] See note, p. 4.

3. *Non-resident work.*—After being admitted to the Graduate Schools, the student may be allowed to substitute non-resident work for resident work to a limited extent, under conditions to be arranged in consultation with the Dean and the heads of the departments concerned.

4. *Work done in other universities.*—Graduate work done in another university will be accepted as equivalent to resident work in the University of Chicago, provided the institution in which the work was done is of high standing, and sufficient evidence is furnished that the particular work was satisfactorily performed.

Work done in other universities will not ordinarily count for more than one and one-half years of resident work in the University; but the degree of Doctor of Philosophy may, in exceptional cases, be granted after one year of residence.[1]

5. *Thesis.*—The thesis presented in fulfillment of the requirement for the Doctor's degree must be upon some question connected with his principal subject, and must constitute an actual contribution to knowledge. Its subject must be submitted for approval to the head of the department at least twelve months before the date of the final examination; the thesis itself must be submitted in written form to the head of the department three months before the date of the final examination, and after criticism, in revised and typewritten form, six weeks before the date of the final examination. After acceptance, *one hundred* printed copies of the same must be deposited in the Library. The theses thus deposited become the property of the University.

6. *Final examination.*—After admission to candidacy the student may present himself for examination in his secondary subject or subjects as soon as he has fulfilled the requirements of the department or departments concerned. He may present himself for the examination in his principal subject, or in both principal and secondary subjects if the examination in the latter has not been taken in advance, as soon as he has (1) fulfilled the requirements of the department or departments concerned, and (2) presented to the Dean a written certificate from the principal department concerned that the thesis is ready for the printer. The examination will be conducted by a committee consisting of the members of the principal department concerned, an appointed representative of the secondary department, or a representative of each of them if there are two, of any other members of the secondary department who may choose to attend, and a member of some other department appointed by the Dean of the Ogden (Graduate) School. If the examinations in the secondary subjects are separated, they may not be held in the same quarter, or within two months of each other.

The candidate is required to prepare a typewritten or printed brief of his work, including an analysis of the thesis, and to file six copies of the same with his Dean for distribution to the committee one week before the examination. In the case of the examination in the secondary department, the statement should

[1] In order to avoid misunderstandings, candidates for higher degrees should consult with their Deans concerning all technical requirements for such degrees, before application is made for admission to candidacy.

include the work in this department; and the brief for the final examination should include all the work presented for the degree.

7. *Conferring the degree.*—The Doctor's degree will not be conferred until the thesis has been published, and 100 copies deposited with the Library, exception being made only in case the thesis is to be published by the United States Government or the Carnegie Institution. In this case the degree may be granted on presentation to the proper Faculty, through the head of the department, of a statement from the proper officer of the Government or the Carnegie Institution that the thesis in completed form has been received and accepted for publication. [In effect after October 1, 1908.]

FELLOWSHIPS AND SCHOLARSHIPS

To students who had shown evidence of marked ability in these departments, and who gave promise of distinction in original investigation, thirteen Fellowships were awarded during the year 1907–8.

Candidates for Fellowships and Scholarships should apply to the Deans of the Graduate Schools on blanks furnished for the purpose. Applications must be received at the Deans' offices *not later than March 1 of each year*, in order to be considered for the following year. Appointments will be made early in April.

Fellows may be called upon for assistance in teaching in the University, or for kindred work; but in no case will they be expected or permitted to devote more than one-sixth of their time to such service. Fellows will not engage in outside work for compensation except by permission of the President. Except in rare cases, students will not be appointed to fellowships until they have done at least one year of graduate work.

Several Scholarships, each yielding the larger part of all of the tuition fees for three quarters ($120), are assigned annually to students in these departments. One graduate Scholarship, yielding a sum sufficient to pay the annual tuition fees, is annually awarded to the student in each department graduated from the University of Chicago during the preceding year, with the highest standing.

A Scholarship of the amount of the tuition fees for three quarters ($120) is awarded annually in each department offering Junior College work to the student passing from the Junior to the Senior Colleges with the highest standing.

OTHER AID TO STUDENTS

Besides Fellowships and Scholarships various kinds of assistance are offered to those who need help, under the following heads: (1) Prizes; (2) Remission of Tuition; (3) University Service; (4) Other Service in the University; (5) Loans by the Students' Fund Society, and (6) Outside Employment. The position of the University in a large city brings the decided advantage of providing many opportunities for employment. Through the University Employment Bureau, in the period from January 1 to July 1, 1906, students were reported as earning $21,660.37. For further details, applicants should send for the circular, *Assistance to Students at the University of Chicago.*

MATHEMATICS

OFFICERS OF INSTRUCTION

Eliakim Hastings Moore, Ph.D., LL.D., Professor and Head of the Department of Mathematics.

Oskar Bolza, Ph.D., Professor of Mathematics.

Herbert Ellsworth Slaught, Ph.D., Associate Professor of Mathematics.

Jacob William Albert Young, Ph.D., Associate Professor of the Pedagogy of Mathematics.

Leonard Eugene Dickson, Ph.D., Associate Professor of Mathematics.

William Hoover, Ph.D., Non-Resident University Extension Assistant Professor of Mathematics.

Arthur Constant Lunn, Ph.D., Instructor in Applied Mathematics.

William Duncan MacMillan, A.M., Associate in Mathematics and Astronomy.

Henry Seely White, Ph.D., Professor of Mathematics, Vassar College (Summer Quarter, 1908).

George William Myers, Ph.D., Professor of the Teaching of Mathematics and Astronomy, the School of Education.

Gilbert Ames Bliss, Ph.D., Assistant Professor of Mathematics, Princeton University (Summer Quarter, 1908).

FELLOWS, 1908–9

Thomas Buck, S.B.

Lloyd Lyne Dines, A.B., A.M.

Egbert J. Miles, A.B.

Arthur Dunn Pitcher, A.B., A.M

GENERAL STATEMENT

The regular Junior College courses are: courses 1, 2, 3, 4, 5, 6, 7, 8, 15, 18, 19, and 20. Students of the College of Science and of the College of Arts are required to take course 1.

Students who expect to specialize in Mathematics, Astronomy, or Physics should confer with the instructors in Mathematics in planning their courses. They should take courses 1, 2, 3, 18, 19, and 20. It is possible, however, for students of exceptional ability in Mathematics to pass from course 2 to Course 18, if course 3 is taken at the same time as 18. Students who desire to have at least a glimpse beyond the elements of Mathematics should elect course 3 or 15 or both.

The following courses introductory to the higher Mathematics are intended both (1) for students making Mathematics their principal subject, and (2) for

those making Mathematics their secondary subject, in particular for students of Astronomy and Physics: (A) †Differential and integral calculus (3 Mj); (B) †Solid analytics and determinats; algebraic analysis (2 Mjs); (C) †Analytic mechanics; theoretical mechanics; vector analysis; theory of the potential (2 Mj); (D) † Advanced calculus, including differential equations, definite integrals, Fourier series, elements of elliptic integrals, elements of the theory of functions (3 Mj); (E) Synthetic projective geometry; analytic projective geometry; differential geometry (2 Mj); (F) Theory of numbers; theory of invariants; selected chapters of algebra; theory of substitutions with applications to algebraic equations; quaternions.

Groups (A)–(F) indicate six sequences of courses running through the usual academic year from October to June. These sequences vary slightly from year to year, the courses marked (†) are given annually, and the other courses usually once in two years.

The undergraduate student who wishes to specialize in Mathematics should take the courses of group (A) as Junior College Electives, those of (B) in his first Senior College year, and those of (C) and (D) in his second Senior College year.

The courses of groups (A)–(F) and the special courses in the higher Mathematics are intended to give the graduate student a comprehensive view of modern Mathematics, to develop him to scientific maturity, and to enable him to follow, without further guidance, the scientific movement of the day in Mathematics, and, if possible, to take an active part in it by creative research. The special and research courses vary from year to year. They may be classified, in general, as relating to (*a*) Algebra and Arithmetic; (*b*) Analysis; (*c*) Geometry; (*d*) Mechanics and Applied Mathematics; and (*e*) the Foundations and Interrelations of the Mathematical Disciplines as purely abstract deductive systems. Attention is called to courses of type (*d*) offered by the Departments of Astronomy and Physics.

The proper arrangement of courses is a matter of extreme importance, and the best arrangement for any student depends on his previous mathematical studies, and can be determined best by conference with some member of the Department.

The courses of the Summer Quarter are designed to meet the needs of those college men and others wishing to study advanced Mathematics, who are able to spend only the summer in residence. The courses of a series of four summer quarters will be arranged so as to give a wide view of modern Mathematics.

Scholarship examinations.—The competitive examinations for the Senior College Scholarship and for the Graduate Scholarship in Mathematics (p. 7) are held each Spring Quarter at times and places announced in the *Weekly Calendar*. Prospective candidates should confer with the Departmental Examiner in Mathematics. Files of papers set at previous Scholarship examinations are accessible in the Departmental Library. Candidates for the Senior College Scholarship will be examined on courses 1, 2, and 3; those for the Graduate Scholarship on courses 26, 27, 31, 32, 36, 37, 38, and 39.

Models.—A collection of Brill's models: plaster and thread models of quadric surfaces, plaster models of cubic and Kummer's quartic surfaces, models of cyclides and surfaces of constant positive and negative curvature, and thread models of three-dimensional projections of four-dimensional regular bodies.

DEGREES

Master's degree.—Candidates for the Master's degree in Mathematics are expected to offer for examination the subjects covered by the courses of groups (A)–(D), and two majors selected from (E)–(F), or the equivalents of these subjects, and to present a satisfactory thesis on an assigned topic closely related to one of these subjects.

The Degree of Doctor of Philosophy.—Candidates for the Doctor's degree with Mathematics as secondary subject are expected to offer for examination the subjects covered by the courses of groups (A)–(D), or their equivalents.

Candidates for the Doctor's degree with Mathematics as principal subject are expected (1) to offer for examination the subjects covered by fifteen majors of initial courses of groups (A)–(F), and by a considerable body of special courses, in each case presumably most closely related to the subject of the candidate's dissertation, and (2) to present a dissertation, in finished form, embodying valuable results of mathematical inquiry.

PREPARATION FOR TEACHING

Courses in the history and the teaching of Elementary Mathematics—Arithmetic, Algebra, Geometry, Trigonometry, Analytic Geometry, Calculus, Mechanics—are offered by this department and the School of Education. These courses embody the conviction that elementary students need to have their Mathematics made, not easier, but more perfectly intelligible and attractive. To this end it is believed that teachers should more generally appreciate and utilize in instruction the unity of Mathematics, as made up of various closely interrelated parts, and the character of Mathematics, as an ideal science developed by abstraction from various more concrete domains.

COURSES OF INSTRUCTION

Junior College Courses

0. Solid Geometry.—An elementray course based upon entrance Algebra and Plane Geometry. [Not given in 1908–9.]

Note.—Students from accredited preparatory schools may present themselves for examination in this subject *at the University* for college credit.

1. Plane Trigonometry.—Mj. Summer Quarter. Associate Professor Dickson. Autumn Quarter, 4 sections; Dr. Lunn, Mr. MacMillan, and ————; Winter Quarter, 2 sections, Dr. Lunn and Mr. MacMillan. Spring Quarter, Dr. Lunn.

2. College Algebra.—Prerequisite: course 1. Mj. Summer Quarter, Dr. Lunn; Autumn Quarter, 2 sections, Associate Professors Slaught and Dickson; Winter Quarter, 2 sections, Associate Professors Slaught and Young; Spring Quarter, Associate Professor Dickson.

3. Analytic Geometry.—Elements of plane analytics, including the geometry of the conic sections, with an introduction to solid analytics. Prerequisite: courses 1, 2. Mj. Summer Quarter, Associate Professor Slaught. Autumn and Winter Quarters, Associate Professor Dickson; Spring Quarter, Associate Professor Young.

5. Surveying.—Practical application of Plane Trigonometry, including work in the field with surveying instruments. Prerequisite: course 1. Mj. Spring Quarter, Mr. MacMillan.

15. Introductory Calculus.—The elementary fundamental principles, methods and formulas of differential and integral calculus will be carefully studied in connection with simple problems of geometry and the physical sciences. This course is intended primarily for those who do not wish to take the longer course in Calculus (courses 18, 19, and 20). Prerequisite: courses 2 and 3. Mj. Spring Quarter, Associate Professor Young.

18, 19, 20. Calculus, I, II, III.—The fundamental principles and processes of the Differential and Integral Calculus, with much use of graphical methods, and with much attention to the solving of problems illustrating all phases of the theory, and certain important applications to Geometry, Mechanics, and Physics. Prerequisite: courses 2 and 3 (course 3 may be taken simultaneously with course 18.) Three consecutive majors. Autumn, Winter, and Spring Quarters, Associate Professor Slaught.

Senior College Courses

26. Differential Calculus.—Prerequisite: courses 2 and 3 (course 3 may be taken with 26). Mj. Summer Quarter, Associate Professor Young.

27. Integral Calculus.—An elementary course with many applications to Problems of Geometry, Analysis, and Physics. Prerequisite: course 26. Mj. Summer Quarter, Assistant Professor Bliss.

31. Solid Analytics and Determinants.—Prerequisite: courses 3 and 15 or 18. Mj. Spring Quarter, Associate Professor Young.

32. Algebraic Analysis.—The complex number system (of ordinary Algebra); roots of unity; theory of equations. Prerequisite: courses 3 and 15 or 18. Mj. Summer Quarter, Associate Professor Dickson; Winter Quarter, Associate Professor Young.

38. Advanced Integral Calculus.—Including definite integrals and their geometric applications. Prerequisite: course 37. Mj. Summer Quarter, Associate Professor Slaught.

37, 38, 39. Advanced Calculus, I, II, III.—The fundamental principles and processes of the calculus, including the theory of definite integrals, and differential equations, developed in organic relation with problems of Geometry, Mechanics, and Physics. Prerequisite for 37: courses 18, 19, and 20. Autumn, Winter and Spring Quarters.————.

Graduate Courses

Note.—Students should not register for graduate courses until after consultation with instructors.

40. Conferences on the Pedagogy of Mathematics.—Selected topics from the teaching of preparatory and collegiate mathematics will be considered. Mj. Summer Quarter, Associate Professor Young.

65A, C, D. Reading and Research in Pure Mathematics.—When in the judgment of the Department it is advisable that students undertake definite mathematical reading and research not closely connected with any current lecture course or seminar, this work will be directed by Professor Moore or Associate Professor Dickson. Mj. or DMj. Each Quarter.

66A, B, C, D, Reading and Research in Applied Mathematics.—Advisable reading and research will be directed by Professor Moore, Professor Myers, or Dr. Lunn. Mj. or DMj. Each Quarter.

84. Continuous Groups.—An illumination of the fundamental concepts and theorems of the Lie theory in connection with various classes of problems of geometry. Mj. Winter Quarter, Associate Professor Dickson.

85. Differential Equations from the Standpoint of Lie.—Prerequisite: course 39. Mj. Summer Quarter, Assistant Professor Bliss.

94. Theory of Invariants.—The theory of binary quantics ("modern higher algebra") with applications to the theory of equations and to geometry. Prerequisite: courses 32 and 39. Mj. Spring Quarter, Associate Professor Dickson.

112. General Analysis, I, II, III.—A study of the type of general analysis in which at least one of the independent variables of the theory enters without direct characterization as to quality or range of variation, being, for the simplest instances (1) a single fixed element; (2) an element having a fixed finite number of values; (3) an element having a numerable infinitude of values; (4) an element with values corresponding to the real number from 0 to 1, inclusive,—the general theory applying to these and all other instances in which the postulated body of functional relations is verified. The general principles of the analysis are developed in connection with linear differential and integral equations. The course presupposes a good knowledge of the elements of the theory of functions of real variables, and is intended to lead to independent investigations in various chapters of general analysis. Prerequisite: course 38, and a certain general mathematical maturity. Three consecutive majors, Autumn, Winter, and Spring Quarters, Professor Moore.

121. Theory of Functions of a Complex Variable.—Introduction to the algebra and calculus of complex numbers and their geometric representation; conform representation and Cauchy's theory. Prerequisite: courses 37, 38. Mj. Spring Quarter, Dr. Lunn.

126. Linear Differential Equations.—The general theory with particular reference to differential equations of second order. Special study of the hypergeometric function. Prerequisite: course 121. Autumn Quarter, Associate Professor Dickson.

127. Elliptic Functions.—Weierstrass' theory with applications. Prerequisite: course 121. Summer Quarter, Professor White.

141. Modern Analytic Geometry.—Homogeneous (trilinear) co-ordinates; projective properties of conics. Prerequisite: courses 31, 38, and 39. Autumn Quarter, PROFESSOR ————.

142. Higher Plane Curves.—General properties of algebraic curves. Special study of the curves of the third and fourth order. Prerequisite: course 141. Summer Quarter, PROFESSOR WHITE; Winter Quarter, ————.

160. Analytic Mechanics I.—Dynamics of a particle. Prerequisite: courses 26, 27, and 31. Mj. Summer Quarter, DR. LUNN; Mj. Autumn Quarter, ASSOCIATE PROFESSOR MOULTON. (See Astronomy 5).

160A. Analytic Mechanics II.—(See Astronomy 6). Prerequisite: course 160. Mj. Winter Quarter, ASSOCIATE PROFESSOR MOULTON.

161. Vector Analysis.—The elements of vector algebra, vector differentiation and integration, and the linear vector function; illustrated by typical applications to geometry, mechanics, and physics. Prerequisite: courses 31 and 39. ½Mj. Spring Quarter, PROFESSOR MOORE.

162. Theory of Attraction and the Potential.—The potential function of gravitation and electrostatics; Laplace's equation, Green's functions, and harmonic analysis; extensions to cases of heterogeneous media, with sketch of the abstract theory as related to linear differential equations of the second order. Prerequisite: courses 39 and 160A. Mj. Autumn Quarter, DR. LUNN.

163. Differential Equations of Mathematical Physics.—A study of certain typical linear partial differential equations occurring in the analytic representation of physical theories, and of the functional expansions of solutions satisfying given boundary conditions; with special reference to the concrete phenomena and physical analogies from which the abstract theory has been generalized. Prerequisite: courses 39 and 160A. Winter Quarter, DR. LUNN.

181, 182, 183. General Seminar.—For the consideration of reports of current research and of literature, especially of a fundamental or critical nature. Autumn, Winter and Spring Quarters, PROFESSOR MOORE.

COURSES LEADING TO ENGINEERING

Certain courses offered in the University constitute parts of the curriculum in all schools of engineering, and may be pursued with advantage by those planning to enter a school of engineering later. The branches of Engineering for which preparation is offered include Civil, Mechanical, Mining, Chemical, and Electrical Engineering. The courses announced elsewhere in this circular, which form part of the curriculum of Engineering, are the following: Mathematics, courses 1, 2, 3, 18, 19, (20 recommended); Physics 3, 4, 5; Chemistry 2S, 3S, 6, and courses in English, History, and Modern Languages similar to those required of all students in science. These courses may be taken by students preparing for all branches of Engineering. Courses in Drawing, Surveying, and Shop-work, described below, are also open to intending engineers.

Tuition.—All students registered for any of the technical courses mentioned below, except Introduction to Surveying, pay the usual tuition of $40 per quarter, and an additional $10 for each major of technical work. Students paying Engineering tuition may, with the consent of their Dean, take three college courses in addition to one technical course; but students are advised to take only two college courses in addition to one technical course.

COURSES OF INSTRUCTION

1. Freehand Drawing.—The work of this quarter consists in developing the powers of observation, the appreciation of proportion, harmony of form and color. Pencil, charcoal, color, and pen and ink are used as media. Freehand projection drawings of various details of building and cabinet construction, together with their isometric and perspective sketches; freehand projections, with their isometric and perspective sketches, of the conventional solids; light-and-shade studies in black and white, of various solids, casts, vases, etc.; color and pen-and-ink studies of assigned subjects. A series of home-sketches covering the subjects taught is required. Estimated time for required work, outside of classroom periods, 15–30 hours. Required of students in all branches of Engineering. Lectures and classroom work, 10 hours a week (60 hours). M. First Term, Autumn Quarter, Mr. Ferson.

2. Descriptive Geometry and Mechanical Drawing, I.—Use and care of instruments, scales, triangles, etc.; the graphic solution of problems in plane geometry (text: Faunce, *Mechanical Drawing);* elementary lettering; titles, dimensioning. Six drawings required. Estimated time for required work, outside of classroom periods, 15–30 hours. Required of students in all branches of Engineering. Lectures and classroom work, 10 hours a week (60 hours). Prerequisite: course 1. M. Second Term, Autumn Quarter, Mr. Ferson.

3. Descriptive Geometry and Mechanical Drawing, II.—Orthogonal projection of points, lines, planes, and solids; plans, elevations, and sections; projections in first and third angles; application of geometry to problems in machine design. Interpenetrations: their development and their applications to machine design. Isometric and cabinet projection. Shade lines, titles, dimensioning. Ten drawings required. Estimated time for required work, outside of classroom periods, 30–60 hours. Re-

quired of students in all branches of Engineering. Lectures and classroom work, 10 hours a week (120 hours). Prerequisite: course 2. Winter Quarter, MR. FERSON.

4. Descriptive Geometry and Mechanical Drawing, III.—Pure descriptive geometry (text, Church). Projections upon right and oblique planes; intersection of lines, planes, and solids; application of descriptive geometry to problems in elementary machine design. Ten drawings required. Required of students in all branches of Engineering. Estimated time for required work, outside of class-room periods, 30–60 hours. Lectures and classroom work, 10 hours a week (120 hours). Prerequisite: course 3. Spring Quarter, MR. FERSON.

5. Mechanical Engineering Drawing.—Conventional sections for materials; details of machines from given data and formulæ; proportions for bolts, nuts, screw-threads, springs, pipe-couplings, shaft-couplings, journals, etc. (text, Unwin, *Elements of Machine Design, Part I*). Practice in arrangement of material upon the sheet, titles, dimensioning, lettering, and tabular arrangement of data. Freehand sketches and measurements of details of machines, with their office drawings, tracings, and blue-prints. Ten drawings required. Required of students in Mechanical and Electrical Engineering, and recommended to all others. Estimated time for required work, outside of classroom periods, 30–60 hours. Lectures and classroom work, 10 hours a week (120 hours). Prerequisite: course 3. Autumn Quarter, MR. FERSON.

6. Mechanism.—Problems in belts and pulleys, based upon given data and formulæ; gear teeth under the cycloid and involute systems; bevel gears and elliptical gears (text, Grant, *A Treatise on Gear Wheels*). Cams and their graphics; the plain slidevalve; measurement sketches; assembled drawings, tracings, and blue-prints of some machine or parts. Required of students in Mechanical and Electrical Engineering, and recommended to all others. Ten drawings required. Estimated time outside of classroom periods, 30–60 hours. Lectures and classroom work, 10 hours a week (120 hours). Prerequisite: course 5. Winter Quarter, MR. FERSON.

7. Topographical Drawing.—Practice in ornamental titles, borders, scales, the conventional signs used in topographical drawing; the drawing of contour maps, sections; color work applied to map-drawing; computation of areas, volumes, etc., for excavations and fillings. Ten drawings required. The required work may require time outside of classroom periods. Required of all students in Civil and Mining Engineering. Classroom work, 10 hours a week. Hours: 2:00–5:00. Prerequisite: Mathematics 1, Engineering 4. Mj. Winter Quarter, MR. FERSON.

8. Surveying (Course 5, Department of Mathematics).—Field-work with chain, tape, compass, transit, and level (text, Breed and Hosmer, *The Principles and Practice of Surveying*). Required of students in Civil and Mining Engineering. Prerequisite: Mathematics 1, and course 7 above. Spring Quarter, MR. MACMILLAN.

9. Forge and Machine Shop-Work.—Forge: Study of tools and materials used. Instruction in the building and management of fires, heating, bending, twisting, upsetting, drawing-out, welding of iron and steel, tempering of steel. Machine-shop: Study of tools and machinery used; chipping, filing, scraping, fitting, centering, chucking, turning, reaming, finishing, polishing, drilling, tapping, screw-cutting. A certain amount of work will be required of all students, and opportunity for advanced work will be offered to the more ambitious and skilful men. Recommended to mechanical, mining, chemical, and electrical engineers. 10 hours a week. Prerequisite: course 4. Spring Quarter, MESSRS. BACON AND AVERY.

ASTRONOMY AND ASTROPHYSICS

OFFICERS OF INSTRUCTION

Edwin Brant Frost, A.M., Professor of Astrophysics, and Director of the Yerkes Observatory.

Sherburne Wesley Burnam, A.M., Professor of Practical Astronomy, and Astronomer in the Yerkes Observatory.

Edward Emerson Barnard, A.M., Sc.D., Professor of Practical Astronomy, and Astronomer in the Yerkes Observatory.

George Ellery Hale, S.B., Sc.D., LL.D., Non-resident Professor of Astrophysics (Mt. Wilson, Cal.).

Kurt Laves, A.M., Ph.D., Associate Professor of Astronomy.

Forest Ray Moulton, A.B., Ph.D., Associate Professor of Astronomy.

John Adelbert Parkhurst, S.M., Instructor in Practical Astronomy at the Yerkes Observatory.

Storrs Barrows Barrett, A.B., Secretary and Librarian of the Yerkes Observatory.

Robert James Wallace, Instructor in Photophysics at the Yerkes Observatory.

Philip Fox, S.B., Instructor in Astrophysics at the Yerkes Observatory.

William Duncan MacMillan, A.M., Associate in Mathematics and Astronomy.

FELLOW, 1908–9

Herbert Earl Buchanan, A.B.

INSTRUCTIONAL WORK

The work of the Department of Astronomy and Astrophysics is divided into two parts: (1) Work at the University, comprising: (*a*) elementary instruction in general Astronomy, both theoretical and practical; (*b*) preliminary training in the principles and methods of work underlying the science of Astrophysics (given in part in the Department of Physics); (*c*) graduate and research work in Celestial Mechanics. (2) Graduate and research work in Practical Astronomy and Astrophysics in the Yerkes Observatory at Lake Geneva.

In the work at the University, given by Associate Professors Laves and Moulton and Mr. MacMillan, emphasis will be laid on the development of the mathematical principles and methods which form the basis of the mathematical sciences. In addition to the courses in Descriptive Astronomy, Introduction to Celestial Mechanics, and Analytical Mechanics, courses in the various branches of Celestial Mechanics will be given within periods not exceeding three years. The most

fundamental subjects will be arranged so as to recur at regular intervals, while other more special topics will vary from time to time. The general object of the instruction will be (1) to furnish the student an adequate mathematical basis for successful work in Celestial Mechanics; (2) to give experience and preliminary training in the work of observation and reduction; (3) to direct research work in Celestial Mechanics.

FACILITIES

For instruction in Practical Astronomy a student's observatory is maintained, equipped with a modern Warner & Swasey equatorial telescope of 6½ inches' aperture, provided with a filar micrometer, a 5-inch refractor, a 3-inch Bamberg transit instrument, a Bamberg universal instrument, a Riefler sidereal clock, a chronometer, and various smaller accessories. The laboratory courses offered by the Department of Physics afford excellent preliminary training for the work in Astrophysics.

In the work at the Yerkes Observatory, the advanced student is made familiar with modern methods of research in various branches of Practical Astronomy and Astrophysics. The rapid development of the latter science within the last two decades has been fully recognized in the equipment of the Observatory; the special laboratory facilities make many investigations possible which cannot be carried on where the equipment is less complete. In general, the work in progress during the year 1908–9 will include: Researches in solar physics with the spectroscope, spectroheliograph, and photoheliograph; micrometric observations of double stars, planets, satellites, nebulæ, and comets; photographic studies of stellar spectra and determinations of motions in the line of sight; photography of star clusters, nebulæ, etc.; photographic investigations of stellar parallax; research in visual and photographic photometry; special astrophysical researches. The opportunity of taking part in these investigations is deemed of more advantage to the qualified student than set courses of instruction; but regular programs of work, with courses of collateral reading, will be laid out as conditions may require.

Admission to Yerkes Observatory

The Yerkes Observatory is open only to graduate students who have completed the necessary preliminary studies and have had the requisite experience in practical laboratory and observatory work. Students wishing to work at the Observatory should first consult the Director of the Yerkes Observatory, Williams Bay, Wis., and obtain his approval.

DEGREES

The Master's degree.—Students working for a Master's degree in Astronomy are advised to choose three majors of graduate work in the Department of Physics, and six majors in the Department of Astronomy, the last from courses numbered 5 or above.

The degree of Doctor of Philosophy.—The courses prescribed for the Master's degree will meet the requirement for the Doctor's degree, where Astronomy is the minor subject.

Candidates for the Doctor's degree, with Astronomy as major subject, are expected to make their secondary subject either Mathematics or Physics. Students intending to specialize in the lines of Astrophysics will be required to take the work in Theoretical Physics, Advanced Experimental Physics, Sound and Light, and Physical Manipulation. The courses in Astronomy which will be required depend on the phase of the subject which the candidate elects for his special work, and will be arranged for each candidate during the progress of his work.

CLUB

The Departmental Club meets fortnightly for the review of memoirs and books, and for the presentation of results of research. The club is conducted by the members of the faculties of Mathematics and Mathematical Astronomy. Graduate students of Mathematical Astronomy are expected to attend regularly, and, so far as possible, to participate actively in the meetings of the club.

SEQUENCE OF EARLY COURSES

Undergraduate students who desire to specialize in Astronomy are recommended to take course 36 and its antecedents in Mathematics, and courses 3, 5, 6, 22, and 23 in Astronomy, as a basis for further work.

COURSES OF INSTRUCTION

At the University

Junior College Courses

2. Spherical Trigonometry.—Prerequisite: Plane Trigonometry. ½Mj. Winter Quarter, Associate Professor Laves.

3. Descriptive Astronomy.—An elementary course, dealing with fundamental facts, principles, and methods. Frequent access to the observatory. Mj. Summer Quarter, Mr. MacMillan; Autumn Quarter, Associate Professor Moulton; Spring Quarter, Associate Professors Moulton and Laves.

4. Introduction to Surveying.—(Mathematics 5). Mj. Spring Quarter, 2 sections, Mr. MacMillan and Associate Professor Laves.

Senior College Courses

5. Analytic Mechanics, I.—An introductory course. Prerequisite: Mathematics 27. Mj. Autumn Quarter, Associate Professor Moulton.

6. Analytic Mechanics, II.—Prerequisite: Astronomy 5. Mj. Winter Quarter, Associate Professor Moulton.

7. Spherical and Practical Astronomy.—Prerequisite: Mathematics 1 and Astronomy 3. Mj. Autumn Quarter, Mr. MacMillan.

8. History of Physical Science.—(Physics 25). Open to all Senior College students. Mj. Winter Quarter, Associate Professors Moulton and Mann.

GRADUATE COURSES

22. Introduction to Celestial Mechanics, I.—Central forces; demonstration of law of gravitation; problem of two bodies; the ten integrals of planetary motion; considerations on perturbations; Helmholtz's theory of the heat of the sun. Prerequisite: course 5. Mj. Winter Quarter, MR. MACMILLAN.

23. Introduction to Celestial Mechanics, II. (Determination of Orbits and Special Perturbations).—Properties of conic section motion; determination of two geocentric distances from the observations; determination of elements, and methods of improving them; variations of elements; perturbations of rectangular and polar co-ordinates; numerical differentiation and integration. Prerequisite: course 22. Mj. Spring Quarter, MR. MACMILLAN.

28. Tidal Evolution.—Prerequisite: course 23. Winter Quarter, ASSOCIATE PROFESSOR MOULTON.

29. The Problem of Three Bodies.—Prerequisite: course 23. Mj. Spring Quarter, ASSOCIATE PROFESSOR MOULTON.

31, 32, 33. Research Courses at the Observatory.—Prerequisites: See Admission to Yerkes Observatory, p. 16. DMj. Each Quarter, PROFESSOR FROST AND OTHERS.

PHYSICS

OFFICERS OF INSTRUCTION

Albert Abraham Michelson, Ph.D., Sc.D., LL.D., F.R.S., Professor and Head of the Department of Physics.

Charles Riborg Mann, Ph.D., Associate Professor of Physics.

Robert Andrews Millikan, Ph.D., Associate Professor of Physics.

Carl Kinsley, A.M., M.E., Assistant Professor of Physics.

Henry Gordon Gale, Ph.D., Assistant Professor of Physics.

George Winchester, Ph.D., Professor of Physics, Washington and Jefferson University (Summer Quarter, 1908).

John Mills, A.M., Instructor in Physics, Western Reserve University (Summer Quarter, 1908).

FELLOWS, 1908–9

Harold DeForest Arnold, Ph.B.

Edwin Sherwood Bishop, L.B., A.M.

J. Harry Clo, S.B.

James Remus Wright, S.B.

INSTRUCTIONAL WORK

The instructional work in Physics is directed toward the following ends: (1) The training of original investigators in physics; (2) the training of men competent to fill college and university positions as teachers of physics; (3) the training of teachers of physics for secondary schools; (4) the training of pre-engineering and pre-medical students for later professional work; (5) the training of the general student in scientific methods of work, and in the understanding of the place of physical science in the modern world. From the most elementary to the most advanced courses, the laboratory and the problem method of instruction are emphasized.

FACILITIES

The Ryerson Physical Laboratory is planned with especial reference to offering the best facilities for research work, the entire lower floor being given up to private research rooms. A well-equipped shop, with skilled instrument makers, furnishes opportunity for the construction of special pieces of research apparatus. The equipment has been selected with reference to the needs of research, and includes spectroscopic instruments of highest power, electrical apparatus for work with alternating and direct currents through all ranges of potential, and

appliances for high and for low temperature work, including a liquid air plant. The library of the department is well-equipped for research purposes. A physics club is conducted by some member of the Department, and meets fortnightly for the discussion of the results of research work done in the Ryerson Laboratory and elsewhere.

DEGREES

All candidates for the S.B. degree who elect their major work in Physics are required to take courses 3, 4, and 5, and either six majors selected from courses 11, 12, 13, 15, 16, 17, 18, and 25, or three of these and three Senior College courses in one of the following departments: Mathematics, Astronomy, Chemistry, Geology or Geography. Pre-enigineering students are required to take courses 3, 4, and 5; pre-medical students are required to take courses 3 and 4.

The Master's degree.—Candidates for the Master's degree in Physics are required to take 8 majors in physics and related subjects, and to present in addition a thesis embodying the results of a laboratory problem. All courses in the Department numbered 11 or above, except course 20, will be counted in satisfaction of this requirement.

The degree of Doctor of Philosophy.—Candidates for the Doctor's degree with Physics as a minor subject, must take courses 3, 4, and 5, and six of the following: 11, 12, 13, 15, 16, 17, 18, 25, 31–36, 51, 52, 53, 57, and 59. When physics is one of two minor subjects, the courses must be arranged by consultation with the Department.

All candidates for the Doctor's degree with Physics as the major subject, must take the following courses: 3, 4, 5, 11, 12, 13, 15, and 25, or their equivalents; 3 majors selected from courses 16, 17, 18, 37, 38, and 39; courses 31–36, and three additional graduate courses selected by the student. Each candidate must also present a thesis embodying the results of original research in some subject approved by the Department. The time required for the thesis work generally varies from three to six quarters.

PREPARATION FOR TEACHING

Students preparing to teach physics in secondary schools are expected to have completed courses 3, 4, 5, 14, and 25, and not less than three of courses 11, 12, 13, 15, 16, 17, and 18. See also courses in Physics in the School of Education.

COURSES OF INSTRUCTION

Junior College Courses

1. Elementary Physics.—A first course in the elements of Physics designed primarily for students who do not present entrance Physics. Mj. Autumn Quarter, Assistant Professor Gale.

2. Elementary Physics.—A continuation of the preceding course, covering the subjects of electricity, sound, and light. Prerequisite: course 1. Mj. Winter Quarter, Assistant Professor Gale.

3. Mechanics, Molecular Physics, and Heat.—A general college course in mechanics, molecular physics, and heat, presented mainly from the experimental point of view. Prerequisite: Entrance Physics, or course 2. Mj. Summer Quarter, 2 sections, PROFESSOR WINCHESTER AND MR. MILLS; Autumn Quarter, 3 sections, ASSISTANT PROFESSOR KINSLEY AND ASSOCIATE PROFESSORS MANN AND MILLIKAN; Winter Quarter, ASSOCIATE PROFESSOR MANN; Spring Quarter, ASSISTANT PROFESSOR GALE.

4. Electricity, Sound, and Light.—A general college course in electricity, sound, and light, presented mainly from the experimental point of view, and involving the performance of eighteen laboratory exercises in electricity, four in sound, and six in light. Prerequisite: Physics 3. Mj. Summer Quarter, 2 sections, PROFESSOR WINCHESTER and MR. MILLS; Winter Quarter, 3 sections, ASSOCIATE PROFESSOR MILLIKAN, ASSISTANT PROFESSORS KINSLEY AND GALE; Spring Quarter, ASSOCIATE PROFESSOR MANN.

5. Lecture Demonstration Course.—A course of lectures, demonstrations, and recitations supplementing Courses 3 and 4 and completing a year's work in college Physics. Recent discoveries and developments in Physics are given especial attention. 5 hours a week. Prerequisite: Physics 4. Mj. Summer Quarter, ASSISTANT PROFESSOR GALE; Spring Quarter, ASSISTANT PROFESSOR KINSLEY.

6. General Survey of Physical Science.—A lecture demonstration course in which familiar physical phenomena are presented and discussed with reference both to their scientific interpretation and to their relations to modern life. Primarily for Arts students. Not accepted in satisfaction of specific requirements in Physics. Mj. Autumn Quarter, ASSOCIATE PROFESSOR MANN.

SENIOR COLLEGE COURSES

11. Heat and Molecular Physics.—A lecture course for advanced and graduate students, covering the Kinetic Theory, Capillarity, Elementary Thermodynamics, Solution, and Electrolysis. Prerequisite: Physics 4 and Calculus. Mj. Winter Quarter, ASSOCIATE PROFESSOR MILLIKAN.

12. Light.—A lecture course for advanced students covering the more important sections of geometrical and physical optics. [Not given in 1908–9.]

13. Electricity and Magnetism.—A course of advanced work in theoretical Electricity and Magnetism, intended to supplement the work in General Physics or to prepare for graduate work. Prerequisite: Physics 4 and Calculus. Mj. Winter Quarter, ASSISTANT PROFESSOR KINSLEY.

14. The Pedagogy of Physics.—A course designed for teachers of Physics in high schools, consisting of lectures and discussions upon choice of subject-matter and methods of presentation best suited to elementary courses in Physics. Prerequisite: courses 3, 4, and 5, or equivalents. M. First Term, Summer Quarter, ASSOCIATE PROFESSOR MILLIKAN.

15. Mechanics and Wave Motion.—A lecture course on the physical meaning and the mathematical derivation of the fundamental equations of Mechanics and Wave Motion. Prerequisite: Physics 4 and Calculus. Mj. Autumn Quarter, ASSISTANT PROFESSOR GALE.

16. Experimental Physics (Advanced): Molecular Physics and Heat.—A course of advanced laboratory work involving the determination of vapor pressures

and densities, coefficients of friction of gases and liquids, molecular electrical conductivities, freezing- and boiling-points, latent and specific heats, high and low temperatures, radio-active constants, etc. Prerequisite: course 4. Mj. Spring Quarter, Associate Professor Millikan.

17. **Experimental Physics (Advanced): Light.**—A course of advanced laboratory work in Light, consisting of accurate measurements in diffraction, dispersion, interference, and polarization. Prerequisite: course 4. Mj. Spring Quarter, Associate Professor Mann.

18. **Experimental Physics (Advanced): Electricity and Magnetism.**—Laboratory work of the same grade as courses 16 and 17, but consisting of measurements in Electricity and Magnetism. Prerequisite: Mathematics 27 and Physics 4. DM. First Term, Summer Quarter and Mj. Autumn Quarter, Assistant Professor Kinsley.

20. **Physical Manipulation.**—A series of exercises not provided in the regular courses of Experimental Physics, but important to the teacher or advanced student. It consists of the following groups:

Group A. *Shop Work* includes the cutting, filing, drilling, tapping, soldering, and polishing of metal, screw cutting, and elementary lathe work.

Group B. *Glass Work* includes the cutting, grinding, drilling, polishing, and testing of glass.

Group C. *Glass Blowing* includes the simpler processes in glass blowing, such as cutting, bending, and joining of tubes, blowing bulbs, sealing in electrodes, etc.

Group D. *Chemical Processes and Physical Preparations* include the silvering of glass, cleaning and distillation of mercury, preparation of fibers for suspension, and materials useful in experimental work.

Laboratory fee, $5. Mj. Summer Quarter, Dr. Winchester and Assistants.

21. **Analytic Mechanics.**—An introductory course (Astronomy 5). Autumn Quarter, Associate Professor Moulton.

25. **History of Physical Science.**—A continuation of course 9 in Philosophy, History of Science (ancient). A discussion of the origin and evolution of modern physical science in its relation to the growth of civilization. Mj. Winter Quarter, Associate Professors Moulton and Mann.

Graduate Courses

31, 32, 33. **Theoretical Physics.**—A series of lectures chiefly in Theoretical Physics, Hydrodynamics, Elasticity, Capillarity, Molecular Physics, Thermodynamics, Wave-motion, Sound, Optical Theories, Electricity and Magnetism. 4 hours a week. Prerequisite: Physics 11, 12, and 13, and Calculus. 3Mj. Autumn, Winter, and Spring Quarters, Professor Michelson.

34, 35, 36. **Theoretical Physics.**—A series of lecture courses. Alternating with 31, 32, and 33. Prerequisite: same as for 31. Autumn, Winter, and Spring Quarters. Professor Michelson. [Not given in 1908–9.]

37, 38, 39. **Experimental Physics.**—A course of laboratory work, chiefly devoted to the repetition of classical experiments, such as, Determination of the Mechanical Equivalent of Heat; Maxwell's "V;" Hertzian Oscillation; Relative and Absolute Wave-lengths, etc. 10 hours a week. Prerequisite: Physics 16, 17, and 18.

3Mj. Autumn, Winter, and Spring Quarters, PROFESSOR MICHELSON AND ASSOCIATE PROFESSOR MANN.

40, 41, 42, 43. Research Course.—This course in intended for graduate students who are prepared to undertake special research. Except in the case of a purely mathematical problem, the entire time is to be devoted to work in the laboratory. DMj. Summer Quarter, ASSOCIATE PROFESSOR MILLIKAN; 3DMj. Autumn, Winter, and Spring Quarters, PROFESSOR MICHELSON AND ASSOCIATE PROFESSOR MANN.

48. Spectrometry.—Laboratory work in photographing and measuring the spectra of various elements. Use of the concave grating, echelon, and interferometer. Prerequisite: two years of college Physics and Calculus. Mj. Winter Quarter, ASSISTANT PROFESSOR GALE.

51. Thermodynamics.—Lectures upon the fundamental principles underlying the mechanical theory of heat and the application of these principles to physical and thermochemical problems. Prerequisite: two years of college Physics and Calculus. 5 hours a week. Mj. Autumn Quarter, ASSOCIATE PROFESSOR MILLIKAN.

52. Electron Theory.—A course of graduate lectures, covering the work of the last ten years on the electrical properties of gases, the electron theory, and radioactivity. Prerequisite: same as for 51. 5 hours a week. Mj. Spring Quarter, ASSOCIATE PROFESSOR MILLIKAN.

57. The Theory of Alternating Currents.—A discussion of stationary and moving circuits, including transformers, transmission circuits, and the various types of dynamos and motors. The lectures will be illustrated by demonstrations of alternating current phenomena. Prerequisite: same as for 51. ASSISTANT PROFESSOR KINSLEY. [Not given in 1908–9.]

58. Use of Alternating Currents.—An experimental course involving the use of alternating current machinery and the study of the distribution of alternating currents in circuits. Electro-magnetic and electro-static induction, the phenomenon of resonance, and the operation of synchronous and induction motors will receive special attention. Prerequisite: Physics 18 and Calculus. M. First Term, Summer Quarter, ASSISTANT PROFESSOR KINSLEY.

59. Modern Spectroscopy.—A lecture course on the theory and use of prisms, plane and concave gratings, the echelon, the interferometer, the radiometer, bolometer, and thermopile in spectroscopy; and a discussion of the laws of emission, of spectral series, of the effects on spectra of pressure, temperature, magnetic field, motion of the medium, and motion in the line of sight. 5 hours a week. Prerequisite: Same as for 51. ASSISTANT PROFESSOR GALE. [Not given in 1908–9.]

CHEMISTRY

OFFICERS OF INSTRUCTION

John Ulric Nef, Ph.D., Professor and Head of the Department of Chemistry.
Alexander Smith, Ph.D., Professor and Director of General and Physical Chemistry.
Julius Stieglitz, Ph.D., Professor of Chemistry.
Herbert Newby McCoy, Ph.D., Associate Professor of Physical Chemistry.
Edith Ethel Barnard, Ph.D., Instructor in Chemistry (Quantitative Analysis).
Andrew Fridley McLeod, Ph.D., Research Instructor in Chemistry.
Herman Irving Schlesinger, Ph.D., Associate in Chemistry.
L. Charles Raiford, A.M., Associate in Chemistry.
Ernest Anderson, S.M., Associate in Chemistry.
Alan W. C. Menzies, S.B., Research Associate in Chemistry.

John Charles Hessler, Ph.D., Professor of Chemistry, James Millikan University, Decatur, Ill. (Summer Quarter, 1908).

FELLOWS, 1908–9

Hilton Ira Jones, A.B.
William Cabler Moore, S.B.
José Ignacio Rosario, A.B., L.B.
Herman Augustus Spoehr, S.B.
Harlan Leo Trumbull, A.B.
Fred Wilbert Upson, S.B.

INSTRUCTIONAL WORK

The Department aims to prepare students (1) to teach in colleges or universities; (2) to teach in secondary schools; (3) to fill positions as technical experts or assistants in chemical industries; (4) to become analysts in commercial and sanitary laboratories. The elementary courses may be taken with advantage by students having none of these ends in view.

Special stress will be placed on thoroughness of preparation and the symmetrical development of the student's knowledge. The object of the courses will be not so much to train specialists as to prepare the student to undertake intelligently all kinds of work of a chemical nature. Those intending to become practical chemists will find a thorough course of purely scientific chemistry the best basis for future specialization in any branch of the subject. Those who incline toward inorganic chemistry will be required to do much physical and a considerable amount of organic work; those proposing to become organic chemists will be required to do work in inorganic chemistry of a more advanced nature than that given in the elementary and analytical courses, and some physical chemistry, etc.

RESEARCH

Students are encouraged to begin research work as soon as their preparation justifies it. Facilities for research in all lines, whether of inorganic, organic, or physical chemistry, are provided. Special opportunities to pursue entirely independent research work will be given to maturer students who have already obtained the Doctor's degree.

DEGREES

The degree of Doctor of Philosophy: Chemistry the major subject.—The requirements for the degree of Doctor of Philosophy are: (1) the presentation of a thesis embodying the result of original research in General Inorganic, Organic, Physico-Organic, or Physical Chemistry. The work on which the thesis is based is usually done under the direction of an officer of the Department. (2) Especially thorough and mature knowledge of the branches of Chemistry touched by the thesis, and sufficient knowledge of other fundamental branches of the science.

The general requirements for all candidates are as follows: courses 1–3 (or 1A, 2A), 4*, 6–9, 60, and 61, and two majors selected from courses 10, 11, 13–19, and 30–32; total twelve majors, of which eight majors are undergraduate work.

Special requirements in addition to the above, arranged according to the thesis subject, are as follows:

General Chemistry.—Courses 50–52, 35 or 63, and two majors taken from Course 13, 30, 31, 32, 36, 37, 63, 64, and 65; total, 6 majors.

Organic Chemistry.—Courses 32, 35, 36, 37, and 50, and one major from Courses 10, 13–19, 51, 52, and 63–65; total, 6 majors.

Physico-Organic Chemistry.—Courses 31, 35, 36, 50, 36 or 64, and one major taken from Courses 10, 13–19, 51, 52, 63, 64, and 65; total, 6 majors.

Physical Chemistry.—Courses 50, 51, 64, and 65, and at least two majors taken from Courses 10, 13–19, 30–32, and 35–37; total, 6 majors.

In addition to one set of these specific requirements, at least six half majors will be chosen from the special lecture courses 40–44, 53–58, 65–71, and 80–81. The research work will require from four to six quarters.

The degree of Doctor of Philosophy, Chemistry the secondary subject.—When Chemistry is a secondary subject, the requirement is determined after conference with the head of the department in which the major work is done. Courses 2, 3, 6, 7, and 8, and four other majors in advance of 8, will be required when Chemistry is the only secondary subject; courses 2, 3, 6, 7, and 8, and one other major, when Chemistry is one of two secondary subjects. Elementary Physical Chemistry (60 and 61) or Organic Chemistry, according as the major subject belongs to the Physical or the Biological Group, is recommended.

The Master's degree.—For the Master's degree a dissertation and eight majors of graduate work in Chemistry are required if all the work is in this Department.

* Course 4 may be omitted when advanced work in Organic Chemistry is taken.

These majors must be selected from courses in advance of 9, with the approval of the head of the department. Courses prerequisite to these must be taken, but cannot be counted in reckoning the eight required majors.

SPECIAL COURSES NOT LEADING TO A HIGHER DEGREE

Special students.—Special or unclassified students, not candidates for a degree, will be received, but in every case they will be required to give evidence, satisfactory to the instructors, that their previous training has been sufficient to enable them to derive full profit from the courses they propose to take.

Preparation for teaching.—While students who have not taken the work required for the Doctor's or Master's degree are not usually recommended for college or university positions, the Bachelor's degree, with a sufficient amount of work in Chemistry, is at present considered preparation for teaching in secondary schools. In general the work in Chemistry should include courses 1, 2, 3, 4, 6, 7, 8, 60, 61, and 80, or their equivalent, as well as work in the College of Education. The prospective teacher in secondary schools should be prepared to teach at least one science besides Chemistry.

Preparation for technical positions.—1. Thorough scientific training in all branches of Chemistry required for the Doctor's degree forms the best basis for a career as a chemical expert in any branch of chemical industry. With this preparation, the principles and details of technical processes are quickly grasped, advances in industrial processes are intelligently followed, and newly discovered principles are readily applied.

2. Students who have taken from ten to fifteen majors of work in the Department are able to fill satisfactorily positions as assistants in technical and analytical laboratories, and after some practical experience, to advance to positions of independent responsibility. Students should take at least courses 1 to 10, inclusive, one or two majors in courses 13–19, and courses 60 and 61. If the student's work is primarily in Organic Chemistry, he should take, if possible, two or three courses selected from Nos. 30–32 and 35–37; if his work is in Inorganic Chemistry primarily, he should take courses 50–52. Students taking the fuller preparation outlined are given the preference in answering requests received by the department; but students with less complete training are also sought by technical firms.

3. The Department gives, with other departments (notably Physics and Mathematics) of the University, and the Department of Manual Training of the University High School, the equivalent of three years of a four-years' course in Chemical Engineering. Students are able to take a large part of this work in the purely scientific fundamental branches, while they are candidates for a Bachelor's degree.

The department does not pledge itself to secure positions for those who have studied in it; but as a matter of fact, competent students find suitable places quickly, and in the past the demand for chemists has far exceeded the supply.

LABORATORY FEES

There is a laboratory fee of $5 per major for all courses involving laboratory work in the Department of Chemistry.

COURSES OF INSTRUCTION

NOTE.—After course 9, the courses are arranged in groups according to subjects: courses 10–29 include courses in Analytical Chemistry, 30–49 in Organic Chemistry, 50–59 in Inorganic Chemistry, 60–71 in Physical Chemistry; 80–89 are general in nature, and 90–93 are research courses. Nos. 12–19, 30–34, 40–43, 60–62, and 68–71 are open to, and suitable for, Senior College students.

PRIMARILY FOR THE JUNIOR COLLEGES

1. Elementary General Chemistry: Inorganic I.—Prerequisite: Preparatory Physics. DM. First Term, Summer Quarter. Classroom, 6 hours a week; laboratory, 12 hours a week; MR. RAIFORD. Mj. Autumn Quarter. Classroom, 3 hours a week; laboratory, 6 hours a week; PROFESSOR SMITH AND MR. RAIFORD. Mj. Spring Quarter, — ———.

2. General Chemistry: Inorganic II.— Continuation of course 1. Prerequisite: course 1. DM. Second Term, Summer Quarter, MR. RAIFORD. Mj. Winter Quarter, PROFESSOR SMITH AND MR. RAIFORD.

3. General Chemistry: Inorganic III.— Continuation of course 2. Prerequisite: course 2. Mj. Spring Quarter, PROFESSOR SMITH.

NOTE.—Coures 1, 2, and 3 are consecutive courses. Separate credit is given for each, but students are not advised to take one course only. The aim of these courses is to give a definite idea of the fundamental principles of chemistry, and not to overburden the student with a mass of unconnected facts. The conception of chemical equilibrium and the modern theory of solutions are freely used. The lectures will be experimental to a considerable extent. The courses are designed to meet the wants not only of those who wish to go deeper into chemistry, but of all who wish to study the science as part of a liberal education. The lectures and classroom work of 1, 2, and 3 may be taken by graduate students without the laboratory work or laboratory fee.

2S. General Chemistry: Inorganic.— First course. For students who have had Preparatory Chemistry. Prerequisite: Preparatory Chemistry and Preparatory Physics, one unit each. DM. First Term, Summer Quarter. Classroom, 6 hours a week; laboratory, 12 hours a week; PROFESSOR SMITH. Mj. Autumn Quarter. Classroom, 3 hours a week; laboratory, 6 hours a week; ASSOCIATE PROFESSOR MCCOY.

3S. General Chemistry: Inorganic.—Continuation of course 2S. DM. Second Term, Summer Quarter, PROFESSOR SMITH. Mj. Winter Quarter, DR. SCHLESINGER.

NOTE.—Course 2, Winter Quarter, is a continuation of course 1, but may be entered by those having credit for admission chemistry. Whenever, in exceptional cases, the preparation of a student in 2S justifies it, qualitative analysis may be substituted for 3S.

4. Elementary Organic Chemistry.—Prerequisite: Course 3 or 3S. Mj. Autumn Quarter. Classroom, 3 hours a week; laboratory, 6 hours a week; PROFESSOR STIEGLITZ. Mj. Spring Quarter, ————.

PRIMARILY FOR THE SENIOR COLLEGES

6. Qualitative Analysis (Introductory Course)—The lectures deal with the chemistry of the analytical reactions, and special attention is given to the development

and application of the laws of equilibrium and solutions. This course is, in an important sense, one in advanced General Chemistry. Classroom, 2 hours a week; laboratory, 8 or 16 hours a week. Prerequisite: course 3 or 3S. Mj. or DM. Summer Quarter, PROFESSOR STIEGLITZ AND DR. SCHLESINGER. Mj. Autumn Quarter, PROFESSOR STIEGLITZ AND DR. SCHLESINGER; Winter Quarter, PROFESSOR STIEGLITZ; Spring Quarter, DR. SCHLESINGER.

NOTE.—Courses 6, 7, and 10 form a continuous course, which may be begun in any quarter. The aim of courses 6, 7, and 10 will be to train the student to do intelligent analytical work, based on a knowledge of the scientific principles of the subject, and to apply and amplify his knowledge of General and Physical Chemistry.

7. Qualitative Analysis.—Continuation of course 6. Mj. or DM. Summer, Autumn, and Spring Quarters, DR. SCHLESINGER; Winter Quarter, PROFESSOR STIEGLITZ.

8. Quantitative Analysis (Introductory Course).—Chiefly laboratory work in gravimetric and volumetric analysis. Laboratory, 8 or 16 hours a week; lecture, 1 hour. Prerequisite: course 7. Medical students will be admitted to the course after having taken course 6. M or DM. First Term, Summer Quarter, DR. BARNARD; M or DM. Second Term, Summer Quarter, MR. ANDERSON; Mj. Autumn, Winter, and Spring Quarters, DR. BARNARD.

NOTE.—Courses 8, 9, and 11 form a continuous course which may be begun in any quarter.

9. Quantitative Analysis.—Continuation of Course 8. Mj. or DM. Laboratory, 10 or 20 hours a week. M or DM. First Term, Summer Quarter, DR. BARNARD; M or DM. Second Term, Summer Quarter, MR. ANDERSON; Mj. Autumn, Winter, and Spring Quarters, DR. BARNARD.

PRIMARILY FOR THE GRADUATE SCHOOL

10. Advanced Qualitative Analysis.—Prerequisite: course 7. Mj. or DM. Laboratory, 10 or 20 hours a week. Open to Senior College students. Continuation of courses 6 and 7. Summer, Autumn, and Spring Quarters, DR. SCHLESINGER; Winter Quarter, PROFESSOR STIEGLITZ.

11. Advanced Quantitative Analysis.—Continuation of courses 8 and 9. Open to students in the Senior Colleges. Mj or DM. 10 or 20 hours a week. Spring Quarter, PROFESSOR STIEGLITZ.

12. Elementary Spectrum Analysis (Qualitative).—Emission (flame and electric spark) and absorption spectra of inorganic substances. Chiefly laboratory work. ½Mj. Winter Quarter, ————.

13–19. Special Methods in Quantitative Analysis.—Chiefly laboratory work.

13.	Electrolytic Methods	½Mj or Mj
14.	Special Mineral Analysis	Mj
15.	Water Analysis	½Mj
16.	Gas Analysis	½Mj
17.	Organic Elementary Analysis	½Mj
18.	Iron and Steel Analysis	½Mj or Mj
19.	Proximate Food Analysis	½Mj or Mj

Prerequisite: course 9. First Term, Summer and Spring Quarters, PROFESSOR STIEGLITZ; Autumn and Winter Quarters, DR. BARNARD.

20. Assaying.—Fire-assay of gold, silver, and lead ores. Prerequisite: Course 9. Winter Quarter, MR. FREAS.

25. Toxicology.—½Mj. Autumn Quarter, PROFESSOR HAINES and ASSISTANT.

26. Poisons and Their Detection.—A conference and laboratory course. M. Second Term, Spring Quarter, PROFESSOR HAINES.

30. Organic Chemistry.—Prerequisite: Qualitative Analysis. Mj. Autumn Quarter, PROFESSOR NEF.

31. Organic Chemistry.—Continuation of course 30. Mj. Winter Quarter, PROFESSOR NEF.

32. Organic Chemistry.— Continuation of course 31. M. First Term, Spring Quarter, PROFESSOR NEF.

NOTE.—Courses 30, 31, and 32 form a continuous course, covering the compounds of carbon, including the fatty and the aromatic series. The aim of the courses will be to take up thoroughly the simpler compounds, going with great detail into the chemical behavior, the characteristic reactions, and relationships of the different classes of organic compounds, and considering with great care the synthetic methods by which they can be obtained. Richter's or Bernthsen's *Organic Chemistry* is used as a reference book; but recent literature will, in special cases, be considered in detail.

33. General Organic Chemistry.—Fatty and aromatic series. Prerequisite: Course 7. Lectures, 5 hours a week. Mj (or M. First Term), Summer Quarter, PROFESSOR HESSLER.

34. Elementary Organic Preparations.—Laboratory work, 10 hours a week. This course is arranged to accompany the lectures of course 33. It may be taken without the lectures by students who have had organic chemistry. Prerequisite: Course 7. M or Mj. Summer Quarter, PROFESSOR HESSLER.

35. Organic Preparations.—Laboratory work, 10 or 20 hours a week. Prerequisite: courses 7 and 9, Organic Chemistry (may be taken simultaneously with lectures on Organic Chemistry), and a reading knowledge of German. DM. First and Second Terms, Summer Quarter, PROFESSOR HESSLER; Mj. Autumn, Winter, and Spring Quarters, PROFESSOR NEF.

36. Organic Preparations.— Continuation of course 35. DM. First and Second Terms, Summer Quarter, PROFESSOR HESSLER; Mj. Autumn, Winter, and Spring Quarters, PROFESSOR NEF.

37. Organic Preparations.— Continuation of course 36. DM. First and Second Terms, Summer Quarter, PROFESSOR HESSLER; Mj. Autumn, Winter, and Spring Quarters, PROFESSOR NEF.

40. Special Chapters of Organic Chemistry.—Lectures. Prerequisite: course 32. M. Second Term, Spring Quarter, PROFESSOR NEF.

41. The Aromatic Series.—Lectures, 2 hours a week. Prerequisite: Organic Chemistry. ½Mj. Spring Quarter, PROFESSOR STIEGLITZ. [Not given in 1908–9.]

42. The Carbohydrates and the Terpenes and Their Derivatives.—Prerequisite: course 31. ½Mj. Winter Quarter, PROFESSOR STIEGLITZ.

43. Organic Nitrogen Derivatives.—Uric acid series, pyridine, quinone-imides, and phenazine compounds; a discussion of the alkaloids, ptomaines, and organic dye-stuffs. Prerequisite: course 31. ½Mj. Spring Quarter, PROFESSOR STIEGLITZ.

44. Physical Chemistry Applied to Organic Problems.—Lectures, 2 hours a week. Prerequisite: courses 31 and 60 and 62. ½Mj. PROFESSOR STIEGLITZ. [Not given in 1908–9.]

50. Inorganic Preparations.—Laboratory work. Prerequisite: course 9, and a reading knowledge of German. Mj or DM. 10 or 20 hours a week. DM. Summer Quarter, PROFESSOR HESSLER; Mj. Autumn and Spring Quarters, ASSOCIATE PROFESSOR MCCOY; Winter Quarter, DR. SCHLESINGER.

51. Inorganic Preparations.— Continuation of course 50. Mj. or DM. Autumn Quarter, ASSOCIATE PROFESSOR MCCOY; Winter Quarter, DR. SCHLESINGER.

52. Inorganic Preparations.— Continuation of course 51. Mj. or DM. Autumn Quarter, ASSOCIATE PROFESSOR MCCOY; Winter Quarter, DR. SCHLESINGER.

53. Physical Chemistry Applied to Problems in General Chemistry.—Prerequisite: College Physics 3, and Chemistry 7. PROFESSOR SMITH. [Not given in 1908–9.]

56. Advanced Inorganic Chemistry.—Two lectures a week on selected topics. Prerequisite: course 7. ½Mj. Winter Quarter, ————. [Not given in 1909.]

57. The Chemistry of Photography.— ———. [Not given in 1908–9.]

58. Debatable Questions in General Chemistry.—For teachers and others. ½Mj. Summer Quarter, ————. [Not given in 1908.]

59. History of Physical Science.—A continuation of Philosophy 9, History of Science (ancient). A discussion of the origin and evolution of modern physical science in its relation to the growth of civilization. Prerequisite: ————. Winter Quarter, MESSRS. MOULTON, MANN, AND SMITH.

60. Elementary Physical Chemistry.—With special reference to Physico-Chemical measurements. Prerequisite: Physics 1, and Chemistry 6. ½Mj. Summer and Spring Quarters, ASSOCIATE PROFESSOR MCCOY.

61. Practical Physical Chemistry.—(Continuation of course 60. ½Mj or M. Autumn Quarter, ASSOCIATE PROFESSOR MCCOY.

62. Practical Chemistry.— Prerequisite: Physics course 1, Chemistry 8. Course 60 should accompany or precede this course. M. First or Second Term, Summer Quarter, or ½Mj for the quarter, ASSOCIATE PROFESSOR MCCOY; ½Mj. Spring Quarter, ASSOCIATE PROFESSOR MCCOY.

63. Advanced Physical Chemistry.—Laboratory course. Prerequisite: Physics 3 and Chemistry 60. Course 65 should accompany or precede this course. Mj. or DM. Autumn and Spring Quarters, ASSOCIATE PROFESSOR MCCOY.

64. Advanced Physical Chemistry.—Laboratory course. Continuation of course 63. Mj or DM. Summer, Autumn, and Spring Quarters, ASSOCIATE PROFESSOR MCCOY.

65. Chemical Dynamics.—Prerequisite: course 60, course 4, and course 15 in Mathematics. ½Mj. Autumn Quarter, ASSOCIATE PROFESSOR MCCOY.

66. Chemical Dynamics and Electro-Chemistry.—Prerequisite: As in course 65. Mj. Summer Quarter, ASSOCIATE PROFESSOR MCCOY.

67. Electro-Chemistry.— Prerequisite: course 60 and course 15 in Mathematics. ½Mj. Spring Quarter, ASSOCIATE PROFESSOR MCCOY.

68. Radio-activity and the Nature of Matter.—Lectures. Prerequisite: course 60. M. First Term, Summer Quarter, ASSOCIATE PROFESSOR MCCOY.

69. Laboratory Course in Radio-activity.—To accompany or follow course 68. ½Mj or M. Summer Quarter, ASSOCIATE PROFESSOR MCCOY.

70. Progress of Physical Chemistry in Last Two Years.—Prerequisite: course 60. M. Second Term, Summer Quarter, ASSOCIATE PROFESSOR MCCOY.

71. The Atomic Theory.—Prerequisite: course 8. ½Mj. Autumn Quarter, ASSOCIATE PROFESSOR MCCOY.

80. Training Course in the Teaching of Chemistry.—This course, for prospective teachers in secondary schools, will include: (1) In autumn, observation of teaching in several schools in the city and reports on the same; (2) in winter, a series of conferences on the didactic of chemistry; (3) in spring, practice-teaching in the University High School and in the Junior Colleges under criticism and supervision. Prerequisite: Chemistry 8, 60, and 62, and Physics 3. The most advanced of these prerequisites may accompany this course. Three ½ Mjs. Autumn, Winter, and Spring Quarters, PROFESSOR SMITH. [Not given in 1908–9.]

81. History of Chemistry.—Two hours a week. ½Mj. Winter Quarter.

———.

82. Club Meetings.—Meetings will be held twice a month. They may be attended by anyone interested. The subjects for the meetings will be announced at least one week in advance. Summer, Autumn, Winter, and Spring Quarters.

90–93. Research Work.—This course will include from 30 to 40 hours a week of laboratory work, under the special direction of some one of the instructors in the department. It is expected that research work for a Doctor's thesis will require 4–6 quarters (4–6 DMj). Before being admitted to research, a candidate must satisfy the instructors of the Department that his previous training has been sufficient.

90. *Research in Organic Chemistry.*—Autumn, Winter, and Spring Quarters, PROFESSOR NEF.

91. *Reseach in General Chemistry.*—First Term, Summer Quarter, and Autumn, Winter, and Spring Quarters, PROFESSOR SMITH.

92. *Research in Organic and Physico-Organic Chemistry.*—First Term, Summer Quarter, and Autumn, Winter, and Spring Quarters, PROFESSOR STIEGLITZ.

93. *Research in Physical Chemistry.*—Summer, Autumn, and Spring Quarters, ASSOCIATE PROFESSOR MCCOY.

DOCTORS OF PHILOSOPHY OF THE UNIVERSITY OF CHICAGO

MATHEMATICS

1896. John Irwin Hutchinson, Assistant Professor of Mathematics, Cornell University.

Leonard Eugene Dickson, Associate Professor of Mathematics, The University of Chicago.

1898. Herbert Ellsworth Slaught, Associate Professor of Mathematics, The University of Chicago.

1899. John Anthony Miller, Professor of Mathematics, Swarthmore College.

1900. Gilbert Ames Bliss, Assistant Professor of Mathematics, Princeton University.

George Lincoln Brown, Professor of Mathematics, South Dakota Agricultural College.

William Gillespie, Preceptor in Mathematics, Princeton University.

Derrick Norman Lehmer, Assistant Professor of Mathematics, University of California.

John Hector McDonald, Instructor in Mathematics, University of California.

Ernest Brown Skinner, Assistant Professor of Mathematics, University of Wisconsin.

1901. William Findlay, Professor of Mathematics, McMaster University.

Thomas Milton Putnam, Assistant Professor of Mathematics, University of California.

1903. Oswald Veblen, Preceptor in Mathematics, Princeton University.

1904. William Henry Bussey, Assistant Professor of Mathematics, University of Minnesota.

Herbert Edwin Jordan, Instructor in Mathematics, Michigan College of Mines.

Arthur Whipple Smith, Assistant Professor of Mathematics, Colgate University.

1905. Thomas Emery McKinney, Associate Professor of Mathematics, Wesleyan University.

Robert Lee Moore, Instructor in Mathematics, Princeton University.

1906. William Raymond Longley, Instructor in Mathematics, Yale University.

Arthur Ranum, Instructor in Mathematics, Cornell University.

Anthony Lispenard Underhill, Instructor in Mathematics, University of Wisconsin.

Buzz M. Walker, Professor of Mathematics and Director of School of Engineering, Mississippi Agricultural and Mechanical College.

1907. George David Birkhoff, Instructor in Mathematics, University of Wisconsin.

Robert Lacey Berger, Instructor in Mathematics, University of Illinois.

Louis Ingold, Instructor in Mathematics, University of Missouri.

Nels Johann Lennes, Instructor in Mathematics, Massachusetts Institute of Technology.

Frederick William Owens, Instructor in Mathematics, Cornell University.

Norman Richard Wilson, Associate Professor of Mathematics, University of Manitoba.

1908. Mary Emily Sinclair, Instructor in Mathematics, Oberlin College.

MATHEMATICAL ASTRONOMY

1900. Forest Ray Moulton, Associate Professor of Astronomy, The University of Chicago.

1903. William Albert Hamilton, Professor of Astronomy, Beloit College.

1904. Arthur Constant Lunn, Instructor in Applied Mathematics, The University of Chicago.

1905. Delonzo Tate Wilson, Assistant Professor of Mathematics, Case School of Applied Science.

1906. Frank Loxley Griffin, Instructor in Mathematics, Williams College.

PHYSICS

1897. Gordon Ferry Hull, Professor of Physics, Dartmouth College.

Isabelle Stone, Principal of American School for Girls, Rome, Italy.

1898. Edwin Sheldon Johonnott, Associate Professor of Physics, Rose Polytechnic Institute.

1899. Henry Gordon Gale, Assistant Professor of Physics, The University of Chicago.

1900. Robert Francis Earhart, Assistant Professor of Physics, Ohio State University.

1901. Fritz Reichmann, Practical Physicist, Troy, N. Y.

1902. Frank Baldwin Jewett, Electrical Engineer, New York City.

1904. Thomas Eaton Doubt, Associate Professor of Physics, Armour Institute, Chicago.

Fannie Cornelia Frisbee, (Mrs. Frank B. Jewett), New York City.

Thomas Carlyle Hebb, Professor of Physics, State Normal School, Marquette, Mich.

1905. Frederic Lendhall Bishop, Assistant Professor of Physics, Bradley Polytechnic Institute, Peoria, Ill.

Glenn Moody Hobbs, Instructor in Physics, University High School, The University of Chicago.

Carleton John Lynde, Professor of Physics, MacDonald College, Quebec, Canada.

1906. William Richards Blair, Government Observatory, Mt. Weather, Va.

Lawrence Emery Gurney, Associate Professor of Physics, University of Idaho.

CHEMISTRY

1894. Adolph Bernhard, Chemist, Stone Creek, O.

Warren Rufus Smith, Professor of Chemistry, Lewis Institute, Chicago, Ill.

1896. Bernard Conrad Hesse, Consulting Chemist, New York City.

Samuel Ellis Swartz, Professor of Chemistry and Physics, Fairmount College, Wichita, Kan.

1897. James Bert Garner, Professor of Chemistry, Wabash College, Crawfordsville, Ind.

Lauder William Jones, Professor of Chemistry, University of Cincinnati.

1898. Frank Burnette Dains, Professor of Chemistry, Washburn College, Topeka, Kan.

Otto Folin, Associate Professor of Biological Chemistry, Harvard Medical School, Boston, Mass.

Elizabeth Jeffreys, Professor of Chemistry, Prichett College, Glasgow, Mo.

Herbert Newby McCoy, Associate Professor of Chemistry, The University of Chicago.

1899. JOHN CHARLES HESSLER, Professor of Chemistry, James Millikan University, Decatur, Ill.

WILLIAM MCPHERSON, Professor of Chemistry, Ohio State University.

JAMES HARVEY RANSOM, Professor of General Chemistry, Purdue University, Lafayette, Ind.

1900. HENRY CHALMERS BIDDLE, Assistant Professor of Chemistry, University of California.

1901. RALPH HARPER MCKEE, Professor of Chemistry, Lake Forest University, Lake Forest, Ill.

1902. SOLOMON FARLEY ACREE, Associate Professor of Chemistry, Johns Hopkins University.

WALLACE APPLETON BEATTY, Research Fellow, Rockefeller Institute, New York.

EUGENE PAUL SCHOCH, Assistant Professor of Chemistry, University of Texas, Austin, Tex.

EDWIN EMERY SLOSSON, Literary Editor of *The Independent*, New York City.

1903. HENRY TABOR UPSON, Vice-President and Manager of Pease Oil Company, Buffalo, N. Y.

1904. MAXWELL ADAMS, Professor of Chemistry, State University, Reno, Nev.

RAYMOND FOSS BACON, Government Chemist, Bureau of Science, Manila, P. I.

WILLIAM MCAFEE BRUCE, Chief Chemist, Kennicot Water Company, Chicago Heights, Ill.

NELLIE ESTHER GOLDTWAITE, Research Assistant in Physiological Chemistry, Rockefeller Institute, New York City.

OSWIN W. WILLCOX, Assistant Chemist, United States Smokeless Powder Works, Dover, N. J.

1905. WILLIAM LLOYD EVANS, Assistant Professor of Chemistry, Ohio State University.

WILLIAM MCCRACKEN, Professor of Natural Sciences, State Normal School, Kalamazoo, Mich.

HERMANN SCHLESINGER, Associate in Chemistry, The University of Chicago.

1906. ROY HUTCHINSON BROWNLEE, Chemist, Standard Oil Company, Whiting, Ind.

CHARLES M. CARSON, Professor of Chemistry, New Brunswick University.

HENRY MAX GOETTSCH, Research Chemist, Mallinchrodt Chemical Works, St. Louis, Mo.

WILLIS STOSE HILPERT, Chemist, American Medical Association, Chicago.

JAMES WRIGHT LAWRIE, Industrial Chemist, Chicago.

ANDREW FRIDLEY MCLEOD, Instructor in Chemistry, The University of Chicago.

1907. EDITH ETHEL BARNARD, Instructor in Chemistry, The University of Chicago.

KATHARINE BLUNT, Instructor-elect in Chemistry, Vassar College, Poughkeepsie, N. Y.

WILLEY DENIS, Assistant Chemist, United States Department of Agriculture, Washington, D. C.

ROBERT ANDERSON HALL, Instructor in Chemistry, Armour Institute, Chicago.

LOUIS ALLEN HIGLEY, Teacher of Chemistry, Zion College, Zion City, Ill.

WILLIAM HORACE ROSS, Assistant Chemist, Agricultural Experiment Station, University of Arizona, Tuscon, Ariz.

LOUIS AGASSIZ TEST, Professor of Chemistry, Occidental College, Los Angeles, Cal.

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The University of Chicago

FOUNDED BY JOHN D. ROCKEFELLER

CIRCULAR OF THE DEPARTMENTS OF

MATHEMATICS, ASTRONOMY AND ASTROPHYSICS, PHYSICS CHEMISTRY

PUBLISHED BY THE UNIVERSITY
1909

CALENDAR FOR THE YEAR 1909–10

1909

June 11	Friday	Junior College Day
June 13	Sunday	Convocation Sunday
June 14	Monday	Class Day Summer Meeting of the University Congregation
June 15	Tuesday	Summer Convocation Alumni Day
June 16	Wednesday	Quarterly Examinations
June 17	Thursday	
June 18	Friday	
June 18	Friday	Spring Quarter ends
June 21	*Monday*	*Summer Quarter begins*
July 5	Monday	Independence Day: a holiday
July 28	Wednesday	Examinations for First Term of Summer Quarter First Term of Summer Quarter ends
July 29	Thursday	Second Term of Summer Quarter begins
Aug. 29	Sunday	Convocation Sunday
Sept. 3	Friday	Examinations for Second Term of Summer Quarter Autumn Convocation Second Term of Summer Quarter ends
Oct. 1	*Friday*	*Autumn Quarter begins*
Nov. 25	Thursday	Thanksgiving Day: a holiday
Dec. 19	Sunday	Convocation Sunday
Dec. 20	Monday	Winter Convocation
Dec. 21	Tuesday	Quarterly Examinations
Dec. 22	Wednesday	
Dec. 23	Thursday	
Dec. 23	Thursday	Autumn Quarter ends

1910

Jan. 3	*Monday*	*Winter Quarter begins* Matriculation and Registration of incoming students
Feb. 12	Saturday	Lincoln's Birthday: a holiday
Feb. 22	Tuesday	Washington's Birthday: a holiday
Mar. 13	Sunday	Convocation Sunday
Mar. 15	Tuesday	Spring Convocation
Mar. 16	Wednesday	Quarterly Examinations
Mar. 17	Thursday	
Mar. 18	Friday	
Mar. 18	Friday	Winter Quarter ends
Mar. 18–27		Quarterly Recess
Mar. 28	*Monday*	*Spring Quarter begins* Matriculation and Registration of incoming students
May 30	Monday	Memorial Day: a holiday
June 10	Friday	Junior College Day
June 11	Saturday	Alumni Day
June 12	Sunday	Convocation Sunday
June 13	Monday	Class Day Summer Meeting of University Congregation
June 14	Tuesday	Summer Convocation
June 15	Wednesday	Quarterly Examinations
June 16	Thursday	
June 17	Friday	
June 17	Friday	Spring Quarter ends

GENERAL INFORMATION

The Organization of the University includes: the Graduate School of Arts and Literature; the Ogden (Graduate) School of Science; the Colleges (Senior, last two years; and Junior, first two years) of Arts, Literature, and Science; the Divinity School, the Law School, Courses in Medicine, the College of Education, the College of Commerce and Administration; the College of Religious and Social Science.

Faculty and Equipment.—The faculty numbers three hundred and seventy-six; the libraries contain 470,856 volumes. The University owns ninety acres of land in Chicago and has thirty-one buildings.

Location of the University.—The University grounds lie on both sides (all buildings on the north side) of the Midway Plaisance between Washington and Jackson Parks, six miles south of the center of Chicago. Electric cars, elevated trains, and the Illinois Central Suburban service reach all railway stations. Baggage and mail service is provided at the Information Office in Cobb Lecture Hall.

The University Year is divided into quarters: the Autumn (October to December); the Winter (January to March); the Spring (April to Mid. June); the Summer (Mid. June to August). For the year 1909–10 the exact dates for the opening of the four quarters are: Summer Quarter, June 21, 1909; Autumn Quarter, October 1; Winter Quarter, January 3, 1910; Spring Quarter, March 28. Students are admitted at the opening of each quarter; graduation exercises are held at the close of each quarter.

The Unit of Work and of Credit is a *major*, i. e., a course of instruction involving four or five recitations or lecture hours per week for a full quarter, or double that number of hours for a term of six weeks. A *minor* is one-half a major. Normal work is three majors per quarter, or nine majors per year of three quarters.

Degrees.—The Graduate Schools confer the degrees of Doctor of Philosophy and of Master of Arts, of Science, and of Philosophy; the Colleges, the degrees of Bachelor of Arts, of Science, of Philosophy; the Divinity School, the degrees of Bachelor of Divinity, Master of Arts, and Doctor of Philosophy; the Law School, the degrees of Doctor of Law and Bachelor of Laws; the School of Education, the degree of the Bachelor of Education.

Tuition, Fees, etc.—The regular fee for three majors in Arts, Literature, and Science, and in the College of Education is $40 per quarter. All students pay once a matriculation fee of $5. In Law and Medicine, the fees are $50 and $60, respectively. Laboratory fees vary from $2.50 to $5 per major per quarter.

Cost of Living.—In University dormitories, rooms rent from $18 to $66 per quarter. Table board in the women's halls is $4.50 per week. At Hutchinson Hall (à la carte service) board costs from $3.50 per week upward. Board and lodging may be had at the same or even lower rates outside the University.

Fellowships, Scholarships, Student Service, etc.—By virtue of endowments and special appropriations, fellowships, scholarships, and service afford stipends or tuition to a number of able and deserving students.

OFFICERS OF ADMINISTRATION

HARRY PRATT JUDSON, President of the University, Haskell Museum, First Floor, Room 10.

ALONZO KETCHAM PARKER, University Recorder, Cobb Lecture Hall, First Floor, Room 2A3.

CHARLES RICHMOND HENDERSON, University Chaplain, Cobb Lecture Hall, First Floor, Room 1.

THOMAS WAKEFIELD GOODSPEED, University Registrar, The Press Building, First Floor, Room 1.

DAVID ALLAN ROBERTSON, Secretary to the President, Haskell Museum, First Floor, Room 10.

GEORGE EDGAR VINCENT, Dean of the Faculties of Arts, Literature, and Science, Cobb Lecture Hall, First Floor, Room 2A5.

ALBION WOODBURY SMALL, Dean of the Graduate School of Arts and Literature, Cobb Lecture Hall, First Floor, Room 2A4.

ROLLIN D. SALISBURY, Dean of the Ogden (Graduate) School of Science, Cobb Lecture Hall, First Floor, Room 2A4.

MARION TALBOT, Dean of Women, Cobb Lecture Hall, First Floor, Room 2A1.

JAMES ROWLAND ANGELL, Dean of the Senior Colleges, Cobb Lecture Hall, First Floor, Room 2A6.

CHARLES EDWARD MERRIAM, Dean of the College of Commerce and Administration.

CHARLES REID BARNES, Examiner for Colleges; FRANK JUSTUS MILLER, Examiner for Secondary Schools, Cobb Lecture Hall, First Floor, Room 8.

ROBERT MORSS LOVETT, Dean of the Junior Colleges, Cobb Lecture Hall, First Floor, Room 2A7.

ALEXANDER SMITH, JAMES WESTFALL THOMPSON, JAMES WEBER LINN, HENRY GORDON GALE, Ellis Hall; WILLIAM DARNALL MACCLINTOCK, SOPHONISBA PRESTON BRECKINRIDGE, ELIZABETH WALLACE, MARION TALBOT, Lexington Hall: Deans in the Junior Colleges.

SOPHONISBA PRESTON BRECKINRIDGE, Assistant Dean of Women, Lexington Hall.

MATHEMATICS, ASTRONOMY AND ASTROPHYSICS, PHYSICS, AND CHEMISTRY

FACILITIES

The equipment of each department will be referred to in the pages which follow, but it may be said for all, that the equipment is adequate for effective instruction and research in all lines in which work is offered. The Departmental Libraries contain files of the more important periodicals relating to these sciences, and most of the treatises and special publications necessary for research work.

DEGREES

Graduate study may lead to the degree of Master of Arts, of Philosophy or of Science, or to the degree of Doctor of Philosophy under the conditions specified below.

I. THE MASTER'S DEGREES

1. *Candidacy.*—Any member of the Graduate Schools who has been in attendance one quarter or more, and whose undergraduate course is equivalent to that required for a corresponding Bachelor's degree in the University of Chicago[1] may, on recommendation by the department or departments in which he is working, be enrolled by vote of the Faculties of the Graduate Schools as a candidate for a Master's degree. Admission to candidacy must precede the conferring of the degree by at least two months.

2. *Requirements.*—Students thus accepted as candidates will be given a Master's degree on fulfilment of the following requirements:

a) At least three quarters' residence at the University.

b) At least eight majors of graduate work. These eight majors need not be all in one department, but must be selected according to some rational plan, approved by the Dean of the Ogden (Graduate) School six months before the degree is conferred. The individual courses must receive the approval of the heads of the departments concerned.

c) A satisfactory dissertation on a subject approved by one of the departments in which the work is done.[2]

d) The delivery of five printed or typewritten copies, including one bound copy, of the dissertation to the University Library, three weeks before the convocation at which the degree is to be conferred.

e) A satisfactory examination on the work taken for the degree.

[1] In case the candidate did not obtain his Bachelor's degree at the University of Chicago, he will present to the University Examiner, on a blank furnished for the purpose, a detailed statement of his undergraduate work.

[2] In exceptional cases, the Dean, upon the recommendation of the department concerned, may accept an additional major in lieu of the dissertation.

II. THE DEGREE OF DOCTOR OF PHILOSOPHY

The degree of Doctor of Philosophy is given, not on the basis of the completion of a certain amount of time spent upon a specified programme, but in recognition of high attainments and ability in the candidate's chosen field, as shown (1) by the production of a thesis evincing the power of independent investigation and forming an actual contribution to existing knowledge; and (2) by the passing of examinations covering the general field of the candidate's studies, with more minuteness in the case of the principal subject, and with less minuteness in the case of the secondary subject or subjects.

1. *Candidacy.*—Any member of the Graduate Schools who has been in attendance one quarter or more, whose undergraduate course is equivalent to that required for a Bachelor's degree in the University of Chicago, whose thesis subject has been accepted by the principal department, and who has a reading knowledge of French and German (which must be certified by those departments) may, on recommendation by the principal department in which he wishes to take his degree, be enrolled, by vote of the Faculties of the Graduate Schools, as a candidate for the Doctor's degree. Admission to candidacy must precede the conferring of the degree by at least two months.

The attention of students is particularly called to the fact that the examination in French and German must be passed before admission to candidacy for the Doctor's degree. It is important that the student should be able to read these subjects early in his university course. To postpone any work necessary for this examination till late in the course is to fail in securing the advantages intended by the regulation.

2. *Requirements.*—Students accepted as candidates will be given the Doctor's degree, on the fulfilment of the following requirements:

a) At least three years of resident work at the University, in pursuance of an accepted course of study. The course in question must include one principal subject, and one or two secondary subjects. The amount of work required in the secondary subject or subjects is nine majors. Candidates should arrange their work as early as possible with the heads of the departments concerned.

b) A satisfactory final examination upon the work done in preparation for the degree.

c) The presentation of a satisfactory printed thesis upon a subject which has been approved by the Head of the Department in which the principal part of the candidate's work has been done.

d) A good command of literary expression, and such knowledge of subjects considered fundamental, as may be prescribed by the several departments.

e) Candidates for the degree of Doctor of Philosophy may not, as a rule, take more than two-thirds of their work in one department, and may not take work which is to count toward the degree in more than three departments.

3. *Non-resident work.*—After being admitted to the Graduate Schools, the student may be allowed to substitute non-resident work for resident work to a

limited extent, under conditions to be arranged in consultation with the Dean and the heads of the departments concerned.

4. *Work done in other universities.*—Graduate work done in another university of high standing will be accepted as equivalent to resident work in the University of Chicago, provided sufficient evidence is furnished that the particular work was satisfactorily performed.

Work done in other universities will not ordinarily count for more than one and one-half years of resident work in the University; but the degree of Doctor of Philosophy may, in exceptional cases, be granted after one year of residence.[1]

5. *Thesis.*—The thesis presented in fulfilment of the requirement for the Doctor's degree must be an investigation of some question connected with the principal subject, and must constitute an actual contribution to knowledge. The subject proposed for investigation must be submitted for approval to the Head of the Department at least twelve months before the date of the final examination; the thesis itself must be submitted in written form to the Head of the Department three months before the date of the final examination, and, after criticism, in revised and typewritten form, six weeks before the date of the final examination. After acceptance, one hundred (100) printed copies of the thesis must be deposited in the Library. The copies thus deposited become the property of the University.

6. *Final examination.*—After admission to candidacy the student may present himself for examination in his secondary subject or subjects as soon as he has fulfilled the requirements of the department or departments concerned. He may present himself for the examination in his principal subject, or in both principal and secondary subjects if the examination in the latter has not been taken in advance, as soon as he has (1) fulfilled the requirements of the department or departments concerned, and (2) presented to the Dean a written certificate from the principal department concerned that the thesis is ready for the printer. The examination will be conducted by a committee consisting of the members of the principal department concerned, an appointed representative of the secondary department, or a representative of each of them if there are two, of any other members of the secondary department who may choose to attend, and a member of some other department appointed by the Dean of the Ogden (Graduate) School. If the examinations in the secondary subjects are separated, they may not be held in the same quarter, or within two months of each other.

The candidate is required to prepare a typewritten or printed brief of his work, including an analysis of the thesis, and to file six copies of the same with his Dean for distribution to the committee one week before the examination. In the case of the examination in the secondary department, the statement should include the work in this department; and the brief for the final examination should include all the work presented for the degree.

7. *Conferring the degree.*—The Doctor's degree will not be conferred until the thesis has been published, and 100 copies deposited with the Library, excep-

[1] In order to avoid misunderstandings, candidates for higher degrees should consult with their Deans concerning all technical requirements for such degrees, before application is made for admission to candidacy.

tion being made only in case the thesis is to be published by the United States Government or the Carnegie Institution. In this case the degree may be granted on presentation to the proper Faculty, through the Head of the Department, of a statement from the proper officer of the Government or the Carnegie Institution that the thesis in completed form has been received and accepted for publication.

FELLOWSHIPS AND SCHOLARSHIPS

To students who had shown evidence of marked ability in these departments, and who gave promise of distinction in original investigation, sixteen Fellowships were awarded during the year 1908–9.

Candidates for Fellowships and Scholarships should apply to the Deans of the Graduate Schools on blanks furnished for the purpose. Applications must be received at the Deans' offices *not later than March 1 of each year*, in order to be considered for the following year. Appointments will be made early in April.

Fellows may be called upon for assistance in teaching in the University, or for kindred work; but in no case will they be expected or permitted to devote more than one-sixth of their time to such service. Fellows will not engage in outside work for compensation except by permission of the President. Except in rare cases, students will not be appointed to fellowships until they have done at least one year of graduate work.

Several Scholarships, each yielding the larger part of all of the tuition fees for three quarters ($120), are assigned annually to students in these departments. One graduate Scholarship, yielding a sum sufficient to pay the annual tuition fees, is annually awarded to the student in each department graduated from the University of Chicago during the preceding year, with the highest standing.

A Scholarship of the amount of the tuition fees for three quarters ($120) is awarded annually in each department offering Junior College work to the student passing from the Junior to the Senior Colleges with the highest standing.

OTHER AID TO STUDENTS

Besides Fellowships and Scholarships various kinds of assistance are offered to those who need help, under the following heads: (1) Prizes; (2) Remission of Tuition; (3) University Service; (4) Other Service in the University; (5) Loans by the Students' Fund Society, and (6) Outside Employment. The position of the University in a large city brings the decided advantage of providing many opportunities for employment. Through the University Employment Bureau many students are able to secure all of the outside employment for which they have time. For further details, applicants should send for the circular, *Assistance to Students at the University of Chicago.*

MATHEMATICS

OFFICERS OF INSTRUCTION

Eliakim Hastings Moore, Ph.D., LL.D., Professor and Head of the Department of Mathematics.

Oskar Bolza, Ph.D., Professor of Mathematics.

George William Myers, Ph.D., Professor of the Teaching of Mathematics and Astronomy, the School of Education.

Gilbert Ames Bliss, Ph.D., Associate Professor of Mathematics.

Leonard Eugene Dickson, Ph.D., Associate Professor of Mathematics.

Herbert Ellsworth Slaught, Ph.D., Associate Professor of Mathematics.

Jacob William Albert Young, Ph.D., Associate Professor of the Pedagogy of Mathematics.

William Hoover, Ph.D., Non-Resident University Extension Assistant Professor of Mathematics.

Arthur Constant Lunn, Ph.D., Instructor in Applied Mathematics.

Theophil Henry Hildebrandt, S.M., Assistant in Mathematics.

James Byrnie Shaw, Sc.D., Professor of Mathematics, James Millikin University (Summer Quarter, 1909).

Oliver Dimon Kellogg, Ph.D., Assistant Professor of Mathematics, University of Missouri (Summer Quarter, 1909).

FELLOWS, 1909–10

Lloyd Lyne Dines, A.M.

Egbert J. Miles, A.B.

Arthur Dunn Pitcher, A.M.

Royal Russ Shumway, A.B.

Marion Ballantyne White, A.M.

GENERAL STATEMENT

The regular Junior College courses are: courses 1, 2, 3, 4, 5, 6, 7, 8, 15, 18, 19, and 20. Students of the College of Science and of the College of Arts are required to take course 1.

Students who expect to specialize in Mathematics, Astronomy, or Physics should confer with the instructors in Mathematics in planning their courses. They should take courses 1, 2, 3, 18, 19, and 20. It is possible, however, for students of exceptional ability in Mathematics to pass from course 2 to course 18, if course 3 is taken at the same time as course 18. Students who desire to have at least a glimpse beyond the elements of Mathematics should elect courses 3 and 15.

The following courses introductory to the higher Mathematics are intended both (1) for students making Mathematics their principal subject, and (2) for those making Mathematics their secondary subject, in particular for students of Astronomy and Physics: (A) †Differential and integral calculus (3 Mj); (B) †Solid analytics and determinants; algebraic analysis (2 Mj); (C) †Analytic mechanics; theoretical mechanics; vector analysis; theory of the potential (2 Mj); (D) † Advanced calculus, including differential equations, definite integrals, Fourier series, elements of elliptic integrals, elements of the theory of functions (3 Mj); (E) Synthetic projective geometry; analytic projective geometry; differential geometry; (F) Theory of numbers; theory of invariants; selected chapters of algebra; theory of substitutions with applications to algebraic equations; quaternions.

Groups (A)–(F) indicate six sequences of courses running through the usual academic year from October to June. These sequences vary slightly from year to year, the courses marked (†) are given annually, and the other courses usually once in two years.

The undergraduate student who wishes to specialize in Mathematics should take the courses of group (A) as Junior College Electives, those of (B) in his first Senior College year, and those of (C) and (D) in his second Senior College year.

The courses of groups (A)–(F) and the special courses in the higher Mathematics are intended to give the graduate student a comprehensive view of modern Mathematics, to develop him to scientific maturity, and to enable him to follow, without further guidance, the scientific movement of the day in Mathematics, and, if possible, to take an active part in it by creative research. The special and research courses vary from year to year. They may be classified, in general, as relating to (*a*) Algebra and Arithmetic; (*b*) Analysis; (*c*) Geometry; (*d*) Mechanics and Applied Mathematics; and (*e*) the Foundations and Interrelations of the Mathematical Disciplines as purely abstract deductive systems. Attention is called to courses of type (*d*) offered by the Departments of Astronomy and Physics.

The proper arrangement of courses is a matter of extreme importance; the best arrangement for any student depends on his previous mathematical studies, and should be determined by conference with some member of the Department.

The courses of the Summer Quarter are designed to meet the needs of those college men and others wishing to study advanced Mathematics, who are able to spend only the summer in residence. The courses of a series of four summer quarters will be arranged so as to give a wide view of modern Mathematics.

Scholarship examinations.—The competitive examinations for the Senior College Scholarship and for the Graduate Scholarship in Mathematics are held each Spring Quarter at times and places announced in the *Weekly Calendar*. Prospective candidates should confer with the Departmental Examiner in Mathematics. Files of papers set at previous Scholarship examinations are accessible in the Departmental Library. Candidates for the Senior College

Scholarship will be examined on courses 1, 2, and 3; those for the Graduate Scholarship on courses 18, 19, 20, 31, 32, 37, 38, and 39.

Models.—A collection of Brill's models: plaster and thread models of quadric surfaces, plaster models of cubic and Kummer's quartic surfaces, models of cyclides and surfaces of constant positive and negative curvature, and thread models of three-dimensional projections of four-dimensional regular bodies.

MATHEMATICAL CLUBS

The Departmental Club meets regularly for the review of memoirs and books, and for the presentation of results of research. The club is conducted by the members of the faculties of Mathematics and Mathematical Astronomy. Graduate students of the departments are expected to attend and otherwise to participate in the meetings of the club.

The Junior Mathematical Club, with weekly meetings, is conducted by the graduate students of the departments.

HIGHER DEGREES

Master's degree.—Candidates for the Master's degree in Mathematics are expected to offer for examination the subjects covered by the courses of groups (A)–(D), and two majors selected from (E)–(F), or the equivalents of these subjects, and to present a satisfactory thesis on an assigned topic closely related to one of these subjects.

Degree of Doctor of Philosophy.—Candidates for the Doctor's degree with Mathematics as secondary subject are expected to offer for examination the subjects covered by the courses of groups (A)–(D), or their equivalents.

Candidates for the Doctor's degree with Mathematics as principal subject are expected (1) to offer for examination the subjects covered by fifteen majors of initial courses of groups (A)–(F), and by a considerable body of special courses, in each case presumably most closely related to the subject of the candidates' dissertation, and (2) to present a dissertation, in finished form, embodying valuable results of mathematical inquiry. The subject of the dissertation may be a topic of pure or applied mathematics or of the history, philosophy, or pedagogy of mathematics.

PREPARATION FOR TEACHING

Courses in the history and the teaching of Elementary Mathematics—Arithmetic, Algebra, Geometry, Trigonometry, Analytic Geomentry, Calculus, Mechanics—are offered by this department and the School of Education. These courses embody the conviction that elementary students need to have their Mathematics made, not easier, but more perfectly intelligible and attractive. To this end it is believed that teachers should more generally appreciate and utilize in instruction the unity of Mathematics, as made up of various closely interrelated parts, and the character of Mathematics, as an ideal science developed by abstraction from various more concrete domains.

COURSES OF INSTRUCTION

Junior College Courses

0. Solid Geometry.—An elementary course based upon entrance Algebra and Plane Geometry. [Not given in 1909–10.]

Note.—Students from accredited preparatory schools may present themselves for examination in this subject *at the University* for college credit.

1. Plane Trigonometry.—Mj. Summer Quarter. Professor Shaw. Autumn Quarter, 4 sections; Associate Professor Young, Dr. Lunn, and ———. Winter Quarter, 2 sections, Associate Professor Bliss and Dr. Lunn. Spring Quarter, Dr. Lunn and ———.

2. College Algebra.—Prerequisite: course 1. Mj. Summer Quarter, Professor Shaw; Autumn Quarter, Associate Professor Young; Winter Quarter, 2 sections, Associate Professors Slaught and Young; Spring Quarter, Associate Professor Bliss.

3. Analytic Geometry.—Elements of plane analytics, including the geometry of the conic sections, with an introduction to solid analytics. Prerequisite: courses 1, 2. Mj. Summer Quarter, Assistant Professor Kellogg; Autumn Quarter, Associate Professor Young; Winter Quarter, Dr. MacMillan; Spring Quarter, Associate Professor Slaught.

4. Surveying.—Practical application of Plane Trigonometry, including work in the field with surveying instruments. Prerequisite: course 1. Mj. Spring Quarter, Dr. MacMillan.

7. Elementary Mechanics.—Without the use of Mechanics. Prerequisite: course 1. Mj. Winter Quarter, Dr. Lunn.

15. Introductory Calculus.—The elementary fundamental principles, methods and formulas of differential and integral calculus will be carefully studied in connection with simple problems of geometry and the physical sciences. This course is intended primarily for those who do not wish to take the longer course in Calculus (courses 18, 19, and 20). Prerequisite: courses 1 and 2. Mj. Spring Quarter, Associate Professor Young.

18, 19, 20. Calculus, I, II, III.—The fundamental principles and processes of the Differential and Integral Calculus, with use of graphical methods, and with attention to the solving of problems illustrating all phases of the theory, and certain important applications to Geometry, Mechanics, and Physics. Prerequisite: courses 1, 2, and 3 (course 3 may be taken simultaneously with course 18). Three consecutive majors. Autumn, Winter, and Spring Quarters, 2 sections, Associate Professors Slaught and Bliss.

Senior College Courses

26. Differential Calculus.—A graphic study of rational algebraic functions and of certain simple irrational transcendental functions, yielding material for a geometric introduction to the fundamental notions and processes of the Calculus. Mj. Summer Quarter, Dr. Lunn.

27. Integral Calculus.—A course aimed at a comprehension of the nature of integration and of its applications to Geometry and Physics; solution of numerous problems; use of table of integrals. Prerequisite: course 26. Mj. Summer Quarter, Assistant Professor Kellogg.

31.—Solid Analytical Geometry.—Prerequisite: courses 3 and 15 or 18. Mj. Summer Quarter, Associate Professor Dickson. Autumn Quarter, Professor Bolza.

32, 33. Advanced Algebra, I, II.—The complex number system (of ordinary algebra); roots of unity; theory of equations; determinants; introduction to modern algebra. Prerequisite: courses 3 and 15 or 18. Two consecutive majors. Winter and Spring Quarters, Associate Professor Young.

32. Advanced Algebra, I.—Mj. Summer Quarter. [Not given in 1909.]

35A, B, C. Limits and Series.—Critical theory of convergence of sequences and series of numbers. Sequences and series of functions; uniformity of convergence. Based on Osgood's *Theory of Infinite Series*. Prerequisite: course 18. Three consecutive half majors. Autumn, Winter, and Spring Quarters, DR. LUNN.

35. Limits and Series.—Mj. Summer Quarter, ASSOCIATE PROFESSOR YOUNG.

37, 38, 39. Advanced Calculus, I, II, III.—The fundamental principles and processes of the calculus, including the theory of definite integrals, and differential equations, developed in organic relation with problems of Geometry, Mechanics, and Physics. Prerequisite for 37: courses 18, 19, and 20. Autumn Quarter, ASSOCIATE PROFESSOR SLAUGHT; Winter and Spring Quarters, PROFESSOR BOLZA.

39. Advanced Calculus, III: Definite Integrals.—Theory and applications, in connection with the elements of the theory of elliptic functions. Mj. Summer Quarter, PROFESSOR SHAW.

45. Critical Review of Secondary Mathematics.—(For Teachers.) A brief survey of the subject matter of Secondary Mathematics as seen in the light of modern mathematics, aiming both to organize the theory of the whole scientifically and to gather the products of this work for use in teaching. Prerequisite: working knowledge of Secondary Mathematics. Mj. Summer Quarter, ASSOCIATE PROFESSOR YOUNG.

46. Graphical Methods in Algebra.—(For Teachers.) The cross section paper as a mathematical instrument. M. First Term, Summer Quarter, PROFESSOR MOORE.

GRADUATE COURSES

NOTE.—Students should not register for graduate courses until after consultation with instructors.

65A, B, C, D. Reading and Research in Pure Mathematics.—When in the judgment of the Department it is advisable that students undertake definite mathematical reading and research not closely connected with any current lecture course or seminar, this work will be directed by PROFESSOR MOORE, PROFESSOR BOLZA, ASSOCIATE PROFESSOR BLISS, OR ASSOCIATE PROFESSOR DICKSON. Mj. or DMj. Each Quarter.

66A, B, C. Reading and Research in Applied Mathematics.—Advisable reading and research will be directed by PROFESSOR MOORE, PROFESSOR MYERS, OR DR. LUNN. Mj. or DMj. Each Quarter.

71A, B. Theory of Numbers: A, Theory of Congruences; B, Theory of Algebraic Numbers.—Introductory courses, the second presupposing the first. A: M. First Term; B: M. Second Term, Summer Quarter, ASSOCIATE PROFESSOR DICKSON.

71A. Elements of Theory of Numbers.—½Mj. Autumn Quarter, PROFESSOR MOORE.

74A, B. Theory of Algebraic Numbers.—In particular, Hensel's exhibition of analogies with Weierstrass' theory of functions. A: ½Mj. Winter Quarter; B: ½Mj. Spring Quarter, PROFESSOR MOORE.

84. Continuous Groups.—An illumination of the fundamental concepts and theorems of the Lie theory in connection with various classes of problems of geometry. ASSOCIATE PROFESSOR DICKSON. [Not given in 1909–10.]

85. Differential Equations from the Standpoint of Lie.—Prerequisite: course 39. Mj. ASSOCIATE PROFESSOR BLISS. [Not given in 1909–10.]

94. Theory of Invariants.—The theory of binary quantics ("modern higher algebra") with applications to the theory of equations and to geometry. Prerequisite: courses 32 and 39. Mj. ASSOCIATE PROFESSOR DICKSON. [Not given in 1909–10.]

112A, B, C. Introduction to General Analysis.—A study of the type of general analysis in which at least one of the independent variables is a general variable, that is, a variable which enters the theory without direct characterization as to quality or range of variation, being, for the simplest instances (1) a single fixed element; (2) an element having a fixed finite number of values; (3) an element having a numerable infinitude of values; (4) an element with values corresponding to the real number from 0 to 1, inclusive—the general theory applying to these and to all other instances

in which the postulated body of functional relations is verified. The general principles of the analysis are developed in connection with the fundamental existence theorems of the theory of systems of linear and non-linear differential equations. The course presupposes a good knowledge of the elements of the theory of functions of real variables, and is intended to lead to independent investigations in various chapters of general analysis. Prerequisite: course 38, and a certain general mathematical maturity. Three consecutive half majors. Autumn, Winter, and Spring Quarters, PROFESSOR MOORE.

112A. Introduction to General Analysis.—Prerequisite: course 38 and a certain general mathematical maturity. M. First Term, Summer Quarter, PROFESSOR MOORE.

115A, B, C. Integral Equations in General Analysis.—A development of the theory of Fredholm, Hilbert, and others in the sense of General Analysis. Prerequisite: course 112. Three consecutive half majors. Autumn, Winter, and Spring Quarters, PROFESSOR MOORE.

121. Functions of a Complex Variable: Cauchy's Theory.—Introduction to the algebra and calculus of complex numbers and their geometric representation; conformal representation and Cauchy's theory of functions. Prerequisite: courses 37 and 38. Mj. Spring Quarter. [Not given in 1909–10.]

122. Functions of a Complex Variable: Weierstrass' Theory.—Reading, problems, and lectures. Fundamental theorems on limits and continuity; convergence of series and operations upon them; studies of special functions—algebraic functions and the more usual transcendental ones. Text: Harkness and Morley's *Introduction to Analytic Functions*. Prerequisite: courses 37, 38, and 39. Mj. Summer Quarter, ASSISTANT PROFESSOR KELLOGG. Mj. Autumn Quarter, PROFESSOR BOLZA.

123. Weierstrass' Theory of Elliptic Functions.—Prerequisite: course 122. Mj. Winter Quarter, PROFESSOR BOLZA.

124. Applications of Elliptic Functions.—Especially to problems of Geometry and Mechanics. Prerequisite: course 123. Mj. Spring Quarter, PROFESSOR BOLZA.

126. Linear Differential Equations.—The general theory with particular reference to differential equations of second order. Special study of the hypergeometric function. Prerequisite: course 2. [Not given in 1909–10.]

127. Modern Theories of Analytic Differential Equations with Applications to Celestial Mechanics.—3Mjs. Autumn, Winter, and Spring Quarters, ASSOCIATE PROFESSOR MOULTON.

128A, B. Partial Differential Equations.—Especially the linear equations. Geometrical interpretations. Applications to Geometry and Physics. Prerequisite: course 151. Two consecutive half majors. Winter and Spring Quarters, ASSOCIATE PROFESSOR BLISS.

131. Synthetic Projective Geometry.—Determination of fundamental postulates; theory of one dimensional system of first and second order. M. First Term, Summer Quarter, PROFESSOR MOORE.

141. Modern Analytic Geometry.—Homogeneous (trilinear) co-ordinates; projective properties of conics. Prerequisite: courses 31, 38, and 39. Autumn Quarter. [Not given in 1909–10.]

142. Higher Plane Curves.—General properties of algebraic curves. Special study of the curves of the third and fourth order. Prerequisite: course 141. [Not given in 1909–10.]

151. Differential Geometry.—Theory of twisted curves and surfaces Prerequisite: Advanced Calculus. Mj. Autumn Quarter, ASSOCIATE PROFESSOR BLISS.

160. Analytic Mechanics, I.—(Astronomy 5.) Dynamics of a particle. Prerequisite: courses 26, 27, and 31. Mj. Summer Quarter; Mj. Autumn Quarter, ASSOCIATE PROFESSOR LAVES.

160A. Analytic Mechanics, II.—(Astronomy 6.) Prerequisite: course 160. Mj. Winter Quarter, ASSOCIATE PROFESSOR LAVES.

161. Vector Analysis.—The elements of vector algebra, vector differentia-

tion and integration, and the linear vector function; illustrated by typical applications to Geometry, Mechanics, and Physics. Prerequisite: courses 31 and 39. Mj. Summer Quarter, DR. LUNN.

161A, B, C. Vector Analysis.—Three consecutive half majors. Autumn, Winter and Spring Quarters, DR. LUNN.

162. Theory of Attraction and the Potential.—The potential function of gravitation and electrostatics; Laplace's equation, Green's functions, and harmonic analysis; extensions to cases of heterogeneous media, with sketch of the abstract theory as related to linear differential equations of the second order. Prerequisite: courses 39 and 160A. Mj. DR. LUNN. [Not given in 1909–10.]

163. Differential Equations of Mathematical Physics.—A study of certain typical linear partial differential equations occurring in the analytic representation of physical theories, and of the functional expansions of solutions satisfying given boundary conditions; with special reference to the concrete phenomena and physical analogies from which the abstract theory has been generalized. Prerequisite: courses 39 and 160A. DR. LUNN. [Not given in 1909–10.]

181, 182, 183. General Seminar.—For the consideration of reports of current research and of literature, especially of a fundamental or critical nature. Autumn, Winter and Spring Quarters, PROFESSOR MOORE.

PRE-ENGINEERING COURSES

Certain courses offered in the University constitute parts of the curriculum in all schools of engineering, and may be pursued with advantage by those planning to enter a school of engineering later. The branches of Engineering for which preparation is offered include Civil, Mechanical, Mining, Chemical, and Electrical Engineering. The courses announced elsewhere in this circular, which form part of the curriculum of Engineering, are the following: Mathematics, courses 1, 2, 3, 18, 19 (20 recommended); Physics 3, 4, 5; Chemistry 2S, 3S, 6, and courses in English, History, and Modern Languages similar to those required of all students in science. These courses may be taken by students preparing for all branches of Engineering. Courses in Drawing, Surveying, and Shopwork, described below, are also open to intending engineers.

Tuition.—All students registered for any of the technical courses mentioned below, except Surveying, pay an additional $10 for each major of technical work. Students are advised to take only two college courses in addition to one technical course, but may take another college course as a "fourth course," under the usual restrictions. The tuition for possible combinations is: two or three college courses with one pre-engineering course, $50; one college course with one or two technical courses, $40; a technical course alone, $30; two college courses with two technical courses, $60.

COURSES OF INSTRUCTION

1. Freehand Drawing.—The work of this quarter consists in developing the powers of observation, the appreciation of proportion, harmony of form and color. Pencil, charcoal, color, and pen and ink are used as media. Freehand projection drawings of various details of building and cabinet construction, together with their isometric and perspective sketches; freehand projections, with their isometric and perspective sketches, of the conventional solids; light-and-shade studies in black and white, of various solids, casts, vases, etc.; color and pen-and-ink studies of assigned subjects. A series of home-sketches covering the subjects taught is required. Estimated time for required work, outside of classroom periods, 15–30 hours. Required of students in all branches of Engineering. Lectures and classroom work, 10 hours a week (60 hours). M. First Term, Autumn Quarter, MR. FERSON.

2. Descriptive Geometry and Mechanical Drawing, I.—Use and care of instruments, scales, triangles, etc.; the graphic solution of problems in plane geometry (text: Faunce, *Mechanical Drawing*); elementary lettering; titles, dimensioning. Six drawings required. Estimated time for required work, outside of classroom periods, 15–30 hours. Required of students in all branches of Engineering. Lectures and classroom work, 10 hours a week (60 hours). Prerequisite: course 1. M. Second Term, Autumn Quarter, MR. FERSON.

3. Descriptive Geometry and Mechanical Drawing, II.—Orthogonal projection of points, lines, planes, and solids; plans, elevations, and sections; projections in first and third angles; application of geometry to problems in machine design. Interpenetrations: their development and their applications to machine design. Isometric and cabinet projection. Shade lines, titles, dimensioning. Ten drawings required.

Estimated time for required work, outside of classroom periods, 30–60 hours. Required of students in all branches of Engineering. Lectures and classroom work, 10 hours a week (120 hours). Prerequisite: course 2. Winter Quarter, Mr. Ferson.

4. Descriptive Geometry and Mechanical Drawing, III.—Pure descriptive geometry (text, Church). Projections upon right and oblique planes; intersection of lines, planes, and solids; application of descriptive geometry to problems in elementary machine design. Ten drawings required. Required of students in all branches of Engineering. Estimated time for required work, outside of classroom periods, 30–60 hours. Lectures and classroom work, 10 hours a week (120 hours). Prerequisite: course 3. Spring Quarter, Mr. Ferson.

5. Mechanical Engineering Drawing.—Conventional sections for materials; details of machines from given data and formulae; proportions for bolts, nuts, screw-threads, springs, pipe-couplings, shaft-couplings, journals, etc. (text, Unwin, *Elements of Machine Design, Part I*). Practice in arrangement of material upon the sheet, titles, dimensioning, lettering, and tabular arrangement of data. Freehand sketches and measurements of details of machines, with their office drawings, tracings, and blue-prints. Ten drawings required. Required of students in Mechanical and Electrical Engineering, and recommended to all others. Estimated time for required work, outside of classroom periods, 30–60 hours. Lectures and classroom work, 10 hours a week (120 hours). Prerequisite: course 3. Autumn Quarter, Mr. Ferson.

6. Mechanism.—Problems in belts and pulleys, based upon given data and formulae; gear teeth under the cycloid and involute systems; bevel gears and elliptical gears (text, Grant, *A Treatise on Gear Wheels*). Cams and their graphics; the plain slidevalve; measurement sketches; assembled drawings, tracings, and blue-prints of some machine or parts. Required of students in Mechanical and Electrical Engineering, and recommended to all others. Ten drawings required. Estimated time outside of classroom periods, 30–60 hours. Lectures and classroom work, 10 hours a week (120 hours). Prerequisite: course 5. Winter Quarter, Mr. Ferson.

7. Topographical Drawing.—Practice in ornamental titles, borders, scales, the conventional signs used in topographical drawing; the drawing of contour maps, sections; color work applied to map-drawing; computation of areas, volumes, etc., for excavations and fillings. Ten drawings required. The required work may require time outside of classroom periods. Required of all students in Civil and Mining Engineering. Classroom work, 10 hours a week. Hours: 2–00–5:00. Prerequisite: Mathematics 1, Engineering 4. Mj. Winter Quarter, Mr. Ferson.

8. Surveying (Course 5, Department of Mathematics).—Field-work with chain, tape, compass, transit, and level (text, Breed and Hosmer, *The Principles and Practice of Surveying*). Required of students in Civil and Mining Engineering. Prerequisite: Mathematics 1, and course 7 above. Spring Quarter, Mr. MacMillan.

9. Forge and Machine Shop-Work.—Forge: Study of tools and materials used. Instruction in the building and management of fires, heating, bending, twisting, upsetting, drawing-out, welding of iron and steel, tempering of steel. Machine-shop: Study of tools and machinery used; chipping, filing, scraping, fitting, centering, chucking, turning, reaming, finishing, polishing, drilling, tapping, screw-cutting. A certain amount of work will be required of all students, and opportunity for advanced work will be offered to the more ambitious and skilful men. Recommended to mechanical, mining, chemical, and electrical engineers. 10 hours a week. Prerequisite: course 4. Spring Quarter, Messrs. Bacon and Avery.

ASTRONOMY AND ASTROPHYSICS

OFFICERS OF INSTRUCTION

EDWIN BRANT FROST, A.M., Professor of Astrophysics, and Director of the Yerkes Observatory.

SHERBURNE WESLEY BURNHAM, A.M., Professor of Practical Astronomy, and Astronomer in the Yerkes Observatory.

EDWARD EMERSON BARNARD, A.M., Sc.D., Professor of Practical Astronomy, and Astronomer in the Yerkes Observatory.

GEORGE ELLERY HALE, S.B., Sc.D., LL.D., Non-resident Professor of Astrophysics (Mt. Wilson, Cal.).

KURT LAVES, A.M., PH.D., Associate Professor of Astronomy.

FOREST RAY MOULTON, A.B., PH.D., Associate Professor of Astronomy.

JOHN ADELBERT PARKHURST, S.M., Instructor in Practical Astronomy at the Yerkes Observatory.

STORRS BARROWS BARRETT, A.B., Secretary and Librarian of the Yerkes Observatory.

PHILIP FOX, S.B., Instructor in Astrophysics at the Yerkes Observatory.

WILLIAM DUNCAN MACMILLAN, PH.D., Instructor in Astronomy.

FELLOW, 1909–10

DANIEL BUCHANAN, A.B., A.M.

INSTRUCTIONAL WORK

The work of the Department of Astronomy and Astrophysics is divided into two parts: (1) Work at the University, comprising: (*a*) elementary instruction in general Astronomy, both theoretical and practical; (*b*) preliminary training in the principles and methods of work underlying the science of Astrophysics (given in part in the Department of Physics); (*c*) graduate and research work in Celestial Mechanics. (2) Graduate and research work in Practical Astronomy and Astrophysics in the Yerkes Observatory at Lake Geneva.

In the work at the University, given by Associate Professors Laves and Moulton and Dr. MacMillan, emphasis will be laid on the development of the mathematical principles and methods which form the basis of the mathematical sciences. In addition to the courses in Descriptive Astronomy, Introduction to Celestial Mechanics, and Analytical Mechanics, courses in the various branches of Celestial Mechanics will be given within periods not exceeding three years. The most

fundamental subjects will be arranged so as to recur at regular intervals, while other more special topics will vary from time to time. The general object of the instruction will be (1) to furnish the student an adequate mathematical basis for successful work in Celestial Mechanics; (2) to give experience and preliminary training in the work of observation and reduction; (3) to direct research work in Celestial Mechanics.

FACILITIES

For instruction in Practical Astronomy a student's observatory is maintained. It is equipped with a modern Warner & Swasey equatorial telescope of 6½ inches' aperture, having a filar mecrometer, a 5-inch refractor, a 3-inch Bamberg transit instrument, a Bamberg universal instrument, a Riefler sidereal clock, a chronometer, and various smaller accessories. The laboratory courses offered by the Department of Physics afford excellent preliminary training for the work in Astrophysics.

In the work at the Yerkes Observatory, the advanced student is made familiar with modern methods of research in various branches of Practical Astronomy and Astrophysics. The rapid development of the latter science within the last two decades has been fully recognized in the equipment of the Observatory; the special laboratory facilities make many investigations possible which cannot be carried on where the equipment is less complete. In general, the work in progress during the year 1909–10 will include: Researches in solar physics with the spectroscope, spectroheliograph, and photoheliograph; micrometric observations of double stars, planets, satellites, nebulae, and comets; photographic studies of stellar spectra and determinations of motions in the line of sight; photography of star clusters, nebulae, etc.; photographic investigations of stellar parallax; research in visual and photographic photometry; special astrophysical researches. The opportunity of taking part in these investigations is deemed of more advantage to the qualified student than set courses of instruction; but regular programmes of work, with courses of collateral reading, will be laid out as conditions may require.

Admission to Yerkes Observatory

The Yerkes Observatory is open only to graduate students who have completed the necessary preliminary studies and have had the requisite experience in practical laboratory and observatory work. Students wishing to work at the Observatory should first consult the Director of the Yerkes Observatory, Williams Bay, Wis., and obtain his approval.

DEGREES

The Master's degree.—Students working for a Master's degree in Astronomy are advised to choose three majors of graduate work in the Department of Mathematics or Physics and six majors in the Department of Astronomy, the last from courses numbered 5 to 29.

The degree of Doctor of Philosophy.—The courses prescribed for the Master's degree will meet the requirement for the Doctor's degree, where Astronomy is the minor subject.

Candidates for the Doctor's degree, with Astronomy as major subject, are expected to make their secondary subject either Mathematics or Physics. Students intending to specialize in the lines of Astrophysics will be required to take the work in Theoretical Physics, Advanced Experimental Physics, Sound and Light, and Physical Manipulation. The courses in Astronomy which will be required depend on the phase of the subject which the candidate elects for his special work, and will be arranged for each candidate during the progress of his work.

CLUB

The Departmental Club meets fortnightly for the review of memoirs and books, and for the presentation of results of research. The club is conducted by the members of the faculties of Mathematics and Mathematical Astronomy. Graduate students of Mathematical Astronomy are expected to attend regularly and, so far as possible, to participate actively in the meetings of the club.

SEQUENCE OF EARLY COURSES

Undergraduate students who desire to specialize in Astronomy are recommended to take course 36 and its antecedents in Mathematics, and courses 3, 5, 6, 22, and 23 in Astronomy, as a basis for further work.

COURSES OF INSTRUCTION

At the University

Junior College Courses

2. Spherical Trigonometry.—Prerequisite: Plane Trigonometry. ½Mj. Winter Quarter, Associate Professor Laves.

3. Descriptive Astronomy.—An elementary course, dealing with fundamental facts, principles, and methods. Frequent access to the observatory. Mj. Summer and Autumn Quarters, Associate Professor Laves; Spring Quarter, Associate Professors Moulton and Laves.

4. Introduction to Surveying.—(Mathematics 5.) Mj. Spring Quarter, Dr. MacMillan.

Senior College Courses

5. Analytic Mechanics, I.—An introductory course. Prerequisite: Mathematics 27. Mj. Autumn Quarter, Associate Professor Laves.

6. Analytic Mechanics, II.—Prerequisite: Astronomy 5. Mj. Winter Quarter, Associate Professor Laves.

7. Spherical and Practical Astronomy.—Prerequisite: Mathematics 1 and Astronomy 3. Mj. Spring Quarter, Associate Professor Laves.

8. History of Physical Science.—(Physics 25.) Open to all Senior College students. Mj. Winter Quarter, Associate Professors Moulton and Mann.

Graduate Courses

22. Introduction to Celestial Mechanics, I.—Helmholtz's theory of the heat of the sun. Central forces; demonstration of law of gravitation; problem of two bodies;

the ten integrals of planetary motion; considerations on perturbations. Prerequisite: course 5. Mj. Winter Quarter, DR. MACMILLAN.

23. Introduction to Celestial Mechanics, II.—Properties of conic section motion, special cases of the problem of three bodies; method of variation of parameters; considerations on absolute perturbations; determination of two geocentric distances from the observations; determination of elements and methods of improving them; variations of elements. Prerequisite: course 22. Mj. Spring Quarter, MR. MACMILLAN.

50. Modern Theories of Analytic Differential Equations with Applications to Celestial Mechanics.—(See XVII, 127.) 3Mjs. Autumn, Winter, and Spring Quarters, ASSOCIATE PROFESSOR MOULTON.

31, 32, 33. Research Courses at the Observatory.—Prerequisites: See Admission to Yerkes Observatory, p. 19. DMj. Each Quarter, PROFESSORS FROST, BURNHAM, AND BARNARD, AND MESSRS. FOX AND PARKHURST.

PHYSICS

OFFICERS OF INSTRUCTION

ALBERT ABRAHAM MICHELSON, PH.D., SC.D., LL.D., F.R.S., Professor and Head of the Department of Physics.
CHARLES RIBORG MANN, PH.D., Associate Professor of Physics.
ROBERT ANDREWS MILLIKAN, PH.D., Associate Professor of Physics.
CARL KINSLEY, A.M., M.E., Associate Professor of Physics.
HENRY GORDON GALE, PH.D., Assistant Professor of Physics.
WILLIAM ROSS HAM, A.B., Assistant in Physics.
JOHN YIUBONG LEE, S.B., Assistant in Physics.

GEORGE WINCHESTER, PH.D., Professor of Physics, Washington and Jefferson University (Summer Quarter, 1909).
CHARLES ALBERT PROCTOR, A.B., Assistant Professor of Physics, Dartmouth College (Summer Quarter, 1909).

FELLOWS, 1909–10

J. HARRY CLO, S.B.
WILLIAM HENRY KADESCH, A.B.
HARVEY BRACE LEMON, S.B.
EDWARD JAMES MOORE, A.B., A.M.
JAMES REMUS WRIGHT, S.B.

INSTRUCTIONAL WORK

The instructional work in Physics is directed toward the following ends: (1) The training of original investigators in physics; (2) the training of men competent to fill college and university positions as teachers of physics; (3) the training of teachers of physics for secondary schools; (4) the training of pre-engineering and pre-medical students for later professional work; (5) the training of the general student in scientific methods of work, and in the understanding of the place of physical science in the modern world. From the most elementary to the most advanced courses, the laboratory and the problem method of instruction are emphasized.

FACILITIES

The Ryerson Physical Laboratory is planned with especial reference to offering the best facilities for research work, the entire lower floor being given up to private research rooms. A well-equipped shop, with skilled instrument makers,

furnishes opportunity for the construction of special pieces of research apparatus. The equipment has been selected with reference to the needs of research, and includes spectroscopic instruments of highest power, electrical apparatus for work with alternating and direct currents through all ranges of potential, and appliances for high and for low temperature work, including a liquid air plant. The library of the department is well-equipped for research purposes. A physics club is conducted by some member of the Department, and meets fortnightly for the discussion of the results of research work done in the Ryerson Laboratory and elsewhere.

DEGREES

All candidates for the S.B. degree who elect their major work in Physics are required to take courses 3, 4, and 5, and either six majors selected from courses 11, 12, 13, 15, 16, 17, 18, and 25, or three of these and three Senior College courses in one of the following departments: Mathematics, Astronomy, Chemistry, Geology, or Geography. Pre-engineering students are required to take courses 3, 4, and 5; pre-medical students are required to take courses 3 and 4.

The Master's degree.—Candidates for the Master's degree in Physics are required to take 8 majors in physics and related subjects, and to present in addition a thesis embodying the results of a laboratory problem. All courses in the Department numbered 11 or above, except course 20, will be counted in satisfaction of this requirement.

The degree of Doctor of Philosophy.—Candidates for the Doctor's degree with Physics as a minor subject, must take courses 3, 4, and 5, and six of the following: 11, 12, 13, 15, 16, 17, 18, 25, 31–36, 51, 52, 56, 57, 58, and 59. When physics is one of two minor subjects, the courses must be arranged by consultation with the Department.

All candidates for the Doctor's degree with Physics as the major subject, must take the following courses: 3, 4, 5, 11, 12, 13, 15, and 25, or their equivalent; 3 majors selected from courses 16, 17, 18, 37, 38, and 39; courses 31–36, and three additional graduate courses selected by the student. Each candidate must also present a thesis embodying the results of original research in some subject approved by the Department. The time required for the thesis work generally varies from three to six quarters.

PREPARATION FOR TEACHING

Students preparing to teach physics in secondary schools are expected to have completed courses 3, 4, 5, 14, and 25, and not less than three of courses 11, 12, 13, 15, 16, 17, and 18. See also courses in Physics in the School of Education.

COURSES OF INSTRUCTION

Junior College Courses

1. Elementary Physics.—A first course in the elements of Physics designed primarily for students who do not present entrance Physics. Mj. Autumn Quarter, Assistant Professor Gale.

2. Elementary Physics.—A continuation of the preceding course, covering the subjects of electricity, sound, and light. Prerequisite: course 1. Mj. Winter Quarter, ASSISTANT PROFESSOR GALE.

3. Mechanics, Molecular Physics, and Heat.—A general college course in mechanics, molecular physics, and heat, presented mainly from the experimental point of view. Prerequisite: entrance Physics, or course 2. Mj. Summer Quarter, 2 sections, PROFESSOR WINCHESTER AND MR. HAM. Autumn Quarter, 3 sections, ASSOCIATE PROFESSORS KINSLEY, MANN, AND MILLIKAN; Winter Quarter, ASSOCIATE PROFESSOR KINSLEY; Spring Quarter, ASSOCIATE PROFESSOR MANN.

4. Electricity, Sound, and Light.—A general college course in electricity, sound, and light presented mainly from the experimental point of view, and involving the performance of eighteen laboratory exercises in electricity, four in sound and six in light. Prerequisite: Physics 3. Mj. Summer Quarter, 2 sections, ASSOCIATE PROFESSOR MILLIKAN AND MR. HAM; Winter Quarter, 2 sections, ASSOCIATE PROFESSORS MANN AND MILLIKAN; Spring Quarter, ASSOCIATE PROFESSOR KINSLEY.

5. Lecture Demonstration Course.—A course of lectures, demonstrations, and recitations supplementing courses 3 and 4 and completing a year's work in college Physics. Recent discoveries and developments in Physics are given especial attention. 5 hours a week. Prerequisite: Physics 4. Mj. Summer Quarter, ASSISTANT PROFESSOR GALE; Spring Quarter, ASSOCIATE PROFESSOR MANN.

6. General Survey of Physical Science.—A lecture demonstration course in which familiar physical phenomena are presented and discussed with reference both to their scientific interpretation and to their relations to modern life. Primarily for Arts students. Not accepted in satisfaction of specific requirements in Physics. Mj. [Not given in 1909–10.]

SENIOR COLLEGE COURSES

11. Heat and Molecular Physics.—A lecture course for advanced and graduate students, covering the Kinetic Theory, Capillarity, Elementary Thermodynamics, Solution, and Electrolysis. Prerequisite: Physics 4 and Calculus. Mj. Winter Quarter, ASSOCIATE PROFESSOR MILLIKAN.

12. Light.—A lecture course for advanced students covering the more important sections of geometrical and physical optics. [Not given in 1909–10.]

13. Electricity and Magnetism.—A course of advanced work in theoretical Electricity and Magnetism, intended to supplement the work in General Physics or to prepare for graduate work. Prerequisite: Physics 4 and Calculus. [Not given in 1909–10.]

14. The Pedagogy of Physics.—A course designed for teachers of Physics in high schools, consisting of lectures and discussions upon choice of subject-matter and methods of presentation best suited to elementary courses in Physics. Prerequisite: courses 3, 4, and 5, or equivalents. M. First Term, Summer Quarter, ASSOCIATE PROFESSOR MILLIKAN.

15. Mechanics and Wave Motion.—A lecture course on the physical meaning and the mathematical derivation of the fundamental equations of Mechanics and Wave Motion. Prerequisite: Physics 4 and Calculus. Mj. Autumn Quarter, ASSISTANT PROFESSOR GALE.

16. Experimental Physics (Advanced): Molecular Physics and Heat.—A course of advanced laboratory work involving the determination of vapor pressures and densities, coefficients of friction of gases and liquids, molecular electrical conductivities, freezing- and boiling-points, latent and specific heats, high and low temperatures, radio-active constants, etc. Prerequisite: course 4. Mj. Spring Quarter, ASSOCIATE PROFESSOR MILLIKAN.

17. Experimental Physics (Advanced): Light.—A course of advanced laboratory work in Light, consisting of accurate measurements in diffraction, dispersion, interference, and polarization. Prerequisite: course 4. Mj. Autumn Quarter, ASSOCIATE PROFESSOR MANN.

18. Experimental Physics (Advanced): Electricity and Magnetism.—Laboratory work of the same grade as courses 16 and 17, but consisting of measurements in Electricity and Magnetism. Prerequisite: Mathematics 27 and Physics 4. DM. First Term, Summer Quarter and Mj. Winter Quarter, ASSOCIATE PROFESSOR KINSLEY.

20. Physical Manipulation—A series of exercises not provided in the regular courses of Experimental Physics, but important to the teacher or advanced student. It consists of the following groups.

Group A. *Shop Work* includes the cutting, filing, drilling, tapping, soldering, and polishing of metal, screw cutting, and elementary lathe work.

Group B. *Glass Work* includes the cutting, grinding, drilling, polishing, and testing of glass.

Group C. *Glass Blowing* includes the simpler processes in glass blowing as such cutting, bending, and joining of tubes, blowing bulbs, sealing in electrodes, etc.

Group D. *Chemical Processes and Physical Preparations* include the silvering of glass, cleaning and distillation of mercury, preparation of fibres for suspension, and materials useful in experimental work.

Laboratory fee, $5. Mj. Summer Quarter, DR. WINCHESTER AND ASSISTANTS.

23. Analytic Mechanics.—An introductory course (Astronomy 5). Autumn Quarter, ASSOCIATE PROFESSOR MOULTON.

25. History of Physical Science.—A continuation of course 9 in Philosophy, History of Science (ancient). A discussion of the origin and evolution of modern physical science in its relation to the growth of civilization. Prerequisite: 18 majors credit in college. Mj. Winter Quarter, ASSOCIATE PROFESSORS MOULTON AND MANN.

GRADUATE COURSES

31, 32, 33. Theoretical Physics.—A series of lectures chiefly in Theoretical Physics, Hydrodynamics, Elasticity, Capillarity, Molecular Physics, Thermodynamics, Wave-Motion, Sound, Optical Theories, Electricity and Magnetism. 4 hours a week. Prerequisite: Physics 11, 12, and 13, and Calculus. [Not given in 1909–10.]

34, 35, 36. Theoretical Physics.—A series of lecture courses. Alternating with 31, 32, and 33. Prerequisite: same as for 31. 3Mj. Autumn, Winter, and Spring Quarters, PROFESSOR MICHELSON. 3Mj. Autumn, Winter and Spring Quarters, PROFESSOR MICHELSON.

37, 38, 39. Experimental Physics.—A course of laboratory work, chiefly devoted to the repetition of classical experiments, such as, Determination of the Mechanical Equivalent of Heat; Maxwell's "V;" Hertzian Oscillation; Relative and Absolute Wave-lengths, etc. 10 hours a week. Prerequisite: Physics 16, 17, and 18. 3Mj. Autumn, Winter, and Spring Quarters, PROFESSOR MICHELSON AND ASSOCIATE PROFESSOR MILLIKAN.

40, 41, 42, 43. Research Course.—This course is intended for graduate students who are prepared to undertake special research. Except in the case of a purely mathematical problem, the entire time is to be devoted to work in the laboratory. DMj. Summer, Autumn, Winter, and Spring Quarters, PROFESSOR MICHELSON AND ASSOCIATE PROFESSOR MILLIKAN.

48. Spectrometry, I.—Laboratory work in photographing and measuring the spectra of various elements. Use of the concave grating, echelon, and interferometer. Prerequisite: two years of college Physics and Calculus. Mj. Winter Quarter, ASSISTANT PROFESSOR GALE.

49. Spectrometry, II.—A continuation of course 48. ASSISTANT PROFESSOR GALE. [Not given in 1909–10.]

51. Thermodynamics.—Lectures upon the fundamental principles underlying the mechanical theory of heat and the application of these principles to physical and thermochemical problems. Prerequisite: two years of college Physics and Calculus. 5 hours a week. Mj. Autumn Quarter, ASSOCIATE PROFESSOR MILLIKAN.

52. Electron Theory, I.—A course of graduate lectures, covering the work of the last ten years on the electrical properties of gases, the electron theory, and radio-

activity. Prerequisite: same as for 51. 5 hours a week. Mj. Winter Quarter, ASSOCIATE PROFESSOR MILLIKAN.

53. Electron Theory, II.—A continuation of 52, dealing with the application of the electron theory to metallic conduction, to the Seebeck, Peltier, Thomson, and Hall effects, to optical phenomena in magnetic fields, to the subject of electromagnetic mass, etc. 5 hours a week. Spring Quarter, ASSOCIATE PROFESSOR MILLIKAN.

56. Theory of Electricity and Magnetism.—Modern view of Electricity based on the experimental results of the past twelve years. Discoveries by Roentgen, Zeeman, Thomson, Rutherford, and others. Theories hitherto held and modifications recently introduced. Prerequisite: same as for 51. 5 hours a week. Mj. Summer Quarter, ASSOCIATE PROFESSOR KINSLEY.

57. The Theory of Alternating Currents.—A discussion of stationary and moving circuits, including transformers, transmission circuits, and the various types of dynamos and motors. The lectures will be illustrated by demonstrations of alternating current phenomena. Prerequisite: same as for 51. Mj. Spring Quarter, ASSOCIATE PROFESSOR KINSLEY.

58. Use of Alternating Currents.—An experimental course involving the use of alternating current machinery and the study of the distribution of alternating currents in circuits. Electro-magnetic and electro-static induction, the phenomenon of resonance, and the operation of synchronous and induction motors will receive special attention. Prerequisite: Physics 18 and Calculus. M. First Term, Summer Quarter, ASSOCIATE PROFESSOR KINSLEY.

59. Modern Spectroscopy.—A lecture course on the theory and use of prisms, plane and concave gratings, the echelon, the interferometer, the radiometer, bolometer, the thermopile in spectroscopy; and a discussion of the laws of emission, of spectral series, of the effects on spectra of pressure, temperature, magnetic field, motion of the medium, and motion in the line of sight. 5 hours a week. Prerequisite: same as for 51. ASSISTANT PROFESSOR GALE. [Not given in 1909–10.]

60. Light Waves and Their Uses.—A course of graduate lectures on recent developments in physical optics. Prerequisite: two years of college Physics and Calculus. 3 hours a week. Mj. Summer Quarter, PROFESSOR MICHELSON.

61. Physics Club.—This organization, consisting of all instructors, graduate and advanced students in the Department, meets on Monday of each week from 4:30 to 6:00 for the discussion of recent research.

CHEMISTRY

OFFICERS OF INSTRUCTION

John Ulric Nef, Ph.D., Professor and Head of the Department of Chemistry.
Alexander Smith, Ph.D., Professor and Director of General and Physical Chemistry.
Julius Stieglitz, Ph.D., Professor of Chemistry and Director of Inorganic Chemistry.
Herbert Newby McCoy, Ph.D., Associate Professor of Physical Chemistry.
Thomas Bruce Freas, A.B., Curator.
Edith Ethel Barnard, Ph.D., Instructor in Chemistry (Quantitative Analysis).
Andrew Fridley McLeod, Ph.D., Research Instructor in Chemistry.
Herman Irving Schlesinger, Ph.D., Associate in Chemistry.
L. Charles Raiford, A.M., Associate in Chemistry.
Ernest Anderson, S.M., Associate in Chemistry.
Alan W. C. Menzies, S.B., Research Associate in Chemistry.
Stewart Joseph Lloyd, A.B., Assistant.
William Weldon Hickman, A.B., Research Assistant.
Ethel Mary Terry, A.B., Assistant.

FELLOWS, 1909–10

James Edgar Bell, S.B.
Emma Perry Carr, S.B., Lowenthal Fellow.
Hilton Ira Jones, A.B.
Howard Johnson Lucas, S.B.
William Cabler Moore, S.B.
Peter Peterson, S.B.
José Ignacio Rosario, A.B., L.B.
Herman Augustus Spoehr, S.B.
Harlan Leo Trumbull, A.B.
Fred Wilbert Upson, S.B., Swift Fellow.
Charles Herman Viol, S.B.

INSTRUCTIONAL WORK

The Department aims to prepare students (1) to teach in colleges or universities; (2) to teach in secondary schools; (3) to fill positions as technical experts or assistants in chemical industries; (4) to become analysts in commercial and sanitary laboratories. The elementary courses may be taken with advantage by students having none of these ends in view.

Special stress will be placed on thoroughness of preparation and the symmetrical development of the student's knowledge. The object of the courses will be not so much to train specialists as to prepare the student to undertake intelligently all kinds of work of a chemical nature. Those intending to become

practical chemists will find a thorough course of purely scientific chemistry the best basis for future specialization in any branch of the subject. Those who incline toward inorganic chemistry will be required to do much physical and a considerable amount of organic work; those proposing to become organic chemists will be required to do work in inorganic chemistry of a more advanced nature than that given in the elementary and analytical courses, and some physical chemistry, etc.

RESEARCH

Students are encouraged to begin research work as soon as their preparation justifies it. Facilities for research in all lines, whether of inorganic, organic, or physical chemistry, are provided. Special opportunities to pursue entirely independent research work will be given to maturer students who have already obtained the Doctor's degree.

DEGREES

The degree of Doctor of Philosophy: Chemistry the major subject.—The requirements for the degree of Doctor of Philosophy are: (1) the presentation of a thesis embodying the result of original research in General Inorganic, Organic, Physico-Organic, or Physical Chemistry. The work on which the thesis is based is usually done under the direction of an officer of the Department. (2) Especially thorough and mature knowledge of the branches of Chemistry touched by the thesis, and sufficient knowledge of other fundamental branches of the science.

The general requirements for all candidates are as follows: courses 1–3 (or 1A, 2A), 4*, 6–9, 60, and 61, and two majors selected from courses 10, 11, 13–19, and 30–32; total twelve majors, of which eight majors are undergraduate work.

Special requirements in addition to the above, arranged according to the thesis subject, are as follows:

General Chemistry.—Courses 50–52, 35 or 63, and two majors taken from course 13, 30, 31, 32, 36, 37, 63, 64, and 65; total, 6 majors.

Organic Chemistry.—Courses 32, 35, 36, 37, and 50, and one major from courses 10, 13–19, 51, 52, and 63–65; total, 6 majors.

Physico-Organic Chemistry.—Courses 31, 35, 36, 37, 50, or 63, and one major taken from courses 10, 13–19, 51, 52, 63, 64, and 65; total, 6 majors.

Physical Chemistry.—Courses 50, 51, 63, and 64, and at least two majors taken from courses 10, 13–19, 30–32, and 35–37; total, 6 majors.

In addition to one set of these specific requirements, at least six half majors will be chosen from the special lecture course 40–44, 53–58, 65–71, and 80–81. The research work will require from four to six quarters.

The degree of Doctor of Philosophy: Chemistry the secondary subject.—When Chemistry is a secondary subject, the requirement is determined after conference with the Head of the Department in which the major work is done. Courses 2, 3, 6, 7, and 8, and four other majors in advance of 8, will be required when Chemistry is the only secondary subject; courses 2, 3, 6, 7, and 8, and one other major, when

* Course 4 may be omitted when advanced work in Organic Chemistry is taken.

Chemistry is one of two secondary subjects. Elementary Physical Chemistry (60 and 61) or Organic Chemistry, according as the major subject belongs to the Physical or the Biological Group, is recommended.

The Master's degree.—For the Master's degree a dissertation and eight majors of graduate work in Chemistry are required if all the work is in this Department. These majors must be selected from courses in advance of 9, with the approval of the Head of the Department. Courses prerequisite to these must be taken, but cannot be counted in reckoning the eight required majors.

SPECIAL COURSES NOT LEADING TO A HIGHER DEGREE

Special students.—Special or unclassified students, not candidates for a degree, will be received, but in every case they will be required to give evidence, satisfactory to the instructors, that their previous training has been sufficient to enable them to derive full profit from the courses they propose to take.

Preparation for teaching.—While students who have not taken the work required for the Doctor's or Master's degree are not usually recommended for college or university positions, the Bachelor's degree, with a sufficient amount of work in Chemistry, is at present considered preparation for teaching in secondary schools. In general the work in Chemistry should include courses 1, 2, 3, 4, 6, 7, 8, 60, 61, and 80, or their equivalent, as well as work in the College of Education. The prospective teacher in secondary schools should be prepared to teach at least one science besides Chemistry.

Preparation for technical positions.—1. Thorough scientific training in all branches of Chemistry required for the Doctor's degree forms the best basis for a career as a chemical expert in any branch of chemical industry. With this preparation, the principles and details of technical processes are quickly grasped, advances in industrial processes are intelligently followed, and newly discovered principles are readily applied.

2. Students who have taken from ten to fifteen majors of work in the Department are able to fill satisfactorily positions as assistants in technical and analytical laboratories, and, after some practical experience, to advance to positions of independent responsibility. Students should take at least courses 1 to 10, inclusive, one or two majors in courses 13–19, and courses 60 and 61. If the student's work is primarily in Organic Chemistry, he should take, if possible, two or three courses selected from Nos. 30–32 and 35–37; if his work is in Inorganic Chemistry primarily, he should take courses 50–52. Students taking the fuller preparation outlined are given the preference in answering requests received by the Department; but students with less complete training are also sought by technical firms.

3. The Department gives, with other departments (notably Physics and Mathematics) of the University, and the Department of Manual Training of the University High School, the equivalent of three years of a four-years' course in Chemical Engineering. Students are able to take a large part of this work in the

purely scientific fundamental branches, while they are candidates for a Bachelor's degree.

The Department does not pledge itself to secure positions for those who have studied in it; but as a matter of fact, competent students find suitable places quickly, and in the past the demand for chemists has far exceeded the supply.

LABORATORY FEES

There is a laboratory fee of $5 per major for all courses involving laboratory work in the Department of Chemistry.

COURSES OF INSTRUCTION

NOTE.—After course 9, the courses are arranged in groups according to subjects: courses 10–29 include courses in Analytical Chemistry, 30–49 in Organic Chemistry, 50–59 in Inorganic Chemistry, 60–71 in Physical Chemistry; 80–89, are general in nature and 90–93 are research courses. Nos. 12–19, 30–34, 40–43, 60–62, and 68–71 are open to, and suitable for, Senior College students.

PRIMARILY FOR THE JUNIOR COLLEGES

1. Elementary General Chemistry: Inorganic, I.—Prerequisite: preparatory Physics. DM. First Term, Summer Quarter. Classroom, 6 hours a week; laboratory, 12 hours a week; MR. RAIFORD. Mj. Autumn Quarter. Classroom, 3 hours a week; laboratory, 6 hours a week; PROFESSOR SMITH AND MR. RAIFORD. Mj. Spring Quarter, ———.

2. General Chemistry: Inorganic, II.—(Continuation of course 1.) Prerequisite: course 1. DM. Second Term, Summer Quarter, MR. RAIFORD. Mj. Winter Quarter, PROFESSOR SMITH AND MR. RAIFORD.

3. General Chemistry: Inorganic, III.—(Continuation of course 2.) Prerequisite: course 2. Mj. Spring Quarter, PROFESSOR SMITH.

NOTE.—Courses 1, 2, and 3 are consecutive courses. Separate credit is given for each, but students are not advised to take one course only. The aim of these courses is to give a definite idea of the fundamental principles of Chemistry, and not to overburden the student with a mass of unconnected facts. The conception of chemical equilibrium and the modern theory of solutions are freely used. The lectures will be experimental to a considerable extent. The courses are designed to meet the wants not only of those who wish to go deeper into chemistry, but of all who wish to study the science as part of a liberal education. The lectures and classroom work of 1, 2, and 3 may be taken by graduate students without the laboratory work or laboratory fee.

2S. General Chemistry: Inorganic.—(First Course.) For students who have had Preparatory Chemistry. Prerequisite: preparatory Chemistry and preparatory Physics, one unit each. DM. First Term, Summer Quarter. Classroom, 6 hours a week; laboratory, 12 hours a week; PROFESSOR SMITH. Mj. Autumn Quarter. Classroom, 3 hours a week; laboratory, 6 hours a week; ASSOCIATE PROFESSOR MCCOY.

3S. General Chemistry: Inorganic.—(Continuation of course 2S.) DM. Second Term, Summer Quarter, PROFESSOR SMITH. Mj. Winter Quarter, MR. MENZIES.

NOTE.—Course 2, Winter Quarter, is a continuation of course 1, but may be entered by those having credit for admission chemistry. Whenever, in exceptional cases, the preparation of a student in 2S justifies it, qualitative analysis may be substituted for 3S.

4. Elementary Organic Chemistry.—Prerequisite: course 3 or 3S. Mj. Autumn Quarter. Classroom, 3 hours a week; laboratory, 6 hours a week; PROFESSOR STIEGLITZ. Mj. Spring Quarter, ———.

PRIMARILY FOR THE SENIOR COLLEGES

6. Qualitative Analysis.—(Introductory Course.) The lectures deal with the chemistry of the analytical reactions, and special attention is given to the development and application of the laws of equilibrium and solutions. This course is, in an important sense, one in advanced General Chemistry. Classroom, 2 hours a week; laboratory, 8 or 16 hours a week. Prerequisite: course 3 or 3S. Mj. or DM. Summer Quarter, PROFESSOR STIEGLITZ AND DR. SCHLESINGER. Mj. Autumn Quarter, PRO-

FESSOR STIEGLITZ AND DR. SCHLESINGER; Winter Quarter, PROFESSOR STIEGLITZ; Spring Quarter, DR. SCHLESINGER.

NOTE.—Courses 6, 7, and 10 form a continuous course, which may be begun in any quarter The aim of courses 6, 7, and 10 will be to train the student to do intelligent analytical work, based on a knowledge of the scientific principles of the subject, and to apply and amplify his knowledge of General and Physical Chemistry

7. Qualitative Analysis.—(Continuation of course 6.) Mj. or DM. Summer, Autumn, and Spring Quarters, DR. SCHLESINGER; Winter Quarter, PROFESSOR STIEGLITZ.

8. Quantitative Analysis.—(Introductory Course.) Chiefly laboratory work in gravimetric and volumetric analysis. Laboratory, 8 or 16 hours a week; lecture, 1 hour. Prerequisite: course 7. Medical students will be admitted to the course after having taken course 6. M. or DM. First Term, Summer Quarter, DR. BARNARD; M. or DM. Second Term, Summer Quarter, MR. ANDERSON; Mj. Autumn, Winter, and Spring Quarters, DR. BARNARD.

NOTE.—Courses 8, 9, and 11 form a continuous course which may be begun in any quarter.

9. Quantitative Analysis.—(Continuation of course 8.) Mj. or DM. Laboratory, 10 or 20 hours a week. M. or DM. First Term, Summer Quarter, DR. BARNARD; M. or DM. Second Term, Summer Quarter, MR. ANDERSON; Mj. Autumn, Winter, and Spring Quarters, DR. BARNARD.

PRIMARILY FOR THE GRADUATE SCHOOL

10. Advanced Qualitative Analysis.—Prerequisite: course 7. Mj. or DM. Laboratory, 10 or 20 hours a week. Open to Senior College students. Continuation of courses 6 and 7. Summer, Autumn, and Spring Quarters, DR. SCHLESINGER; Winter Quarter, PROFESSOR STIEGLITZ.

11. Advanced Quantitative Analysis.—(Continuation of courses 8 and 9.) Open to students in the Senior Colleges. Mj. or DM. 10 or 20 hours a week. Spring Quarter, PROFESSOR STIEGLITZ.

12. Elementary Spectrum Analysis (Qualitative).—Emission (flame and electric spark) and absorption spectra of inorganic substances. Chiefly laboratory work. ½Mj. Winter Quarter, ———.

13–19. Special Methods in Quantitative Analysis.—Chiefly laboratory work.

13. Electrolytic Methods	½Mj or Mj
14. Special Mineral Analysis	Mj
15. Water Analysis	½Mj
16. Gas Analysis	½Mj
17. Organic Elementary Analysis	½Mj
18. Iron and Steel Analysis	½Mj or Mj
19. Proximate Food Analysis	½Mj or Mj

Prerequisite: course 9. First Term, Summer, and Spring Quarters, PROFESSOR STIEGLITZ; Autumn and Winter Quarters, DR. BARNARD.

20. Assaying.—Fire-assay of gold, silver, and lead ores. Prerequisite: course 9. Winter Quarter, MR. FREAS.

25. Toxicology.—½Mj. Autumn Quarter, PROFESSOR HAINES AND ASSISTANT.

26. Poisons and Their Detection.—A conference and laboratory course. M. Second Term, Spring Quarter, PROFESSOR HAINES.

30. Organic Chemistry.—Prerequisite: Qualitative Analysis. Mj. Autumn Quarter, PROFESSOR NEF.

31. Organic Chemistry.—(Continuation of course 30.) Mj. Winter Quarter, PROFESSOR NEF.

32. Organic Chemistry.—(Continuation of course 31.) M. First Term, Spring Quarter, PROFESSOR NEF.

NOTE.—Courses 30, 31, and 32 form a continuous course, covering the compounds of carbon, including the fatty and the aromatic series. The aim of the courses will be to take up thoroughly the simpler compounds, going with great detail into the chemical behavior, the characteristic reactions, and relationships of the different classes of organic compounds, and considering with great care the synthetic methods by which they can be obtained. Richter's or Bernthsen's *Organic Chemistry* is used as a reference book; but recent literature will, in special cases, be considered in detail.

33. General Organic Chemistry.—Fatty and aromatic series. Prerequisite: course 7. Lectures, 5 hours a week. Mj. (or M. First Term), Summer Quarter, ———.

34. Elementary Organic Preparations.—Laboratory work, 10 hours a week. This course is arranged to accompany the lectures of course 33. It may be taken without the lectures by students who have had organic chemistry. Prerequisite: course 7. M. or Mj. Summer Quarter, ———.

35. Organic Preparations.—Laboratory work, 10 or 20 hours a week. Prerequisite: courses 7 and 9, Organic Chemistry (may be taken simultaneously with lectures on Organic Chemistry), and a reading knowledge of German. DM. First and Second Terms, Summer Quarter, ———; Mj. Autumn, Winter, and Spring Quarters, PROFESSOR NEF.

36. Organic Preparations.—(Continuation of course 35.) DM. First and Second Terms, Summer Quarter, ———; Mj. Autumn, Winter, and Spring Quarters, PROFESSOR NEF.

37. Organic Preparations.—(Continuation of course 36.) DM. First and Second Terms, Summer Quarter, ———; Mj. Autumn, Winter, and Spring Quarters, PROFESSOR NEF.

40. Special Chapters of Organic Chemistry.—Lectures. Prerequisite: course 32. M. Second Term, Spring Quarter, PROFESSOR NEF.

41. The Aromatic Series.—Lectures, 2 hours a week. Prerequisite: Organic Chemistry. ½Mj. Spring Quarter, PROFESSOR STIEGLITZ.

42. The Carbohydrates and the Terpenes and Their Derivatives.—Prerequisite: course 31. ½Mj. Winter Quarter, PROFESSOR STIEGLITZ. [Not given in 1909–10.]

43. Organic Nitrogen Derivatives.—Uric acid series, pyridine, quinoneimides, and phenazine compounds; a discussion of the alkaloids, ptomaines, and organic dye-stuffs. Prerequisite: course 31. ½Mj. Spring Quarter, PROFESSOR STIEGLITZ.

44. Physical Chemistry Applied to Organic Problems.—Lectures, 2 hours a week. Prerequisite: courses 31 and 60 and 62. ½Mj. Summer Quarter, PROFESSOR STIEGLITZ.

50. Inorganic Preparations.—Laboratory work. Prerequisite: course 9, and a reading knowledge of German. Mj. or DM. 10 or 20 hours a week. DM. Summer Quarter, PROFESSOR HESSLER; Mj. Autumn, Winter, and Spring Quarters, DR. SCHLESINGER.

51. Inorganic Preparations.—(Continuation of course 50.) Mj. or DM. Autumn, Winter, and Spring Quarters, DR. SCHLESINGER.

52. Inorganic Preparations.—(Continuation of course 51.) Mj. or DM. Autumn, Winter and Spring Quarters, DR. SCHLESINGER.

53. Physical Chemistry Applied to Problems in General Chemistry.—Prerequisite: college Physics 3, and Chemistry 7. PROFESSOR SMITH. [Not given in 1909–10.]

56. Advanced Inorganic Chemistry.—Two lectures a week on selected topics. Prerequisite: course 7. ½Mj. Winter Quarter, ———. [Not given in 1910.]

57. The Chemistry of Photography.— ———. [Not given in 1909–10.]

58. Debatable Questions in General Chemistry.—For teachers and others. ½Mj. Summer Quarter, ———. [Not given in 1909.]

59. History of Physical Science.—A continuation of Philosophy 9, History of Science (ancient). A discussion of the origin and evolution of modern physical science in its relation to the growth of civilization. Prerequisite: ———. Winter Quarter, MESSRS. MOULTON, MANN, AND SMITH.

60. Elementary Physical Chemistry, I.—Prerequisite: Physics 1, and Chemistry 6. ½Mj. Summer and Spring Quarters, ASSOCIATE PROFESSOR MCCOY.

61. Elementary Physical Chemistry, II.—(Continuation of course 60.) M. Second Term, Summer Quarter, ASSOCIATE PROFESSOR MCCOY.

62. Physico-Chemical Measurements, I.—Prerequisite: Physics 1, Chemistry 8. Course 60 should accompany or precede this course. M. First or Second Term, Summer Quarter, or ½Mj. for the quarter; ½Mj. Spring Quarter, ASSOCIATE PROFESSOR MCCOY.

63. Physico-Chemical Measurements, II.—Laboratory course. Prerequisite: Physics 3 and Chemistry 60. Course 65 should accompany or precede this course. Mj. or DM. Autumn and Spring Quarters, ASSOCIATE PROFESSOR MCCOY.

64. Physico-Chemical Measurements, III.—Laboratory course. Continuation of course 63. Mj. or DM. Summer, Autumn, and Spring Quarters, ASSOCIATE PROFESSOR MCCOY.

65. Chemical Dynamics.—Prerequisite: course 60, course 4, and course 15 in Mathematics. ½Mj. Autumn Quarter, ASSOCIATE PROFESSOR MCCOY. [Not given in 1909.]

66. Chemical Dynamics and Electro-Chemistry.—Prerequisite: as in course 65. Mj. Summer Quarter, ASSOCIATE PROFESSOR MCCOY. [Not given in 1909.]

67. Electro-Chemistry.—Prerequisite: course 60 and course 15 in Mathematics. ½Mj. Spring Quarter, ASSOCIATE PROFESSOR MCCOY.

68. Radio-activity and the Nature of Matter.—Lectures. Prerequisite: course 60. ½Mj. Summer Quarter, ASSOCIATE PROFESSOR MCCOY.

69. Laboratory Course in Radio-activity.—To accompany or follow course 68. ½Mj. or M. Summer Quarter, ASSOCIATE PROFESSOR MCCOY.

70. Progress of Physical Chemistry in Last Two Years.—Prerequisite: course 60. M. Second Term, Summer Quarter, ASSOCIATE PROFESSOR MCCOY. [Not given in 1909.]

71. The Atomic Theory.—Prerequisite: course 8. ½Mj. Spring Quarter, ASSOCIATE PROFESSOR MCCOY.

80. Training Course in the Teaching of Chemistry.—This course, for prospective teachers in secondary schools, will include: (1) In autumn, observation of teaching in several schools in the city and reports on the same; (2) in winter, a series of conferences on the didactic of chemistry; (3) in spring, practice-teaching in the University High School and in the Junior Colleges under criticism and supervision. Prerequisite: Chemistry 8, 60, and 62, and Physics 3. The most advanced of these prerequisites may accompany this course. Three ½ Mjs. Autumn, Winter, and Spring Quarters, PROFESSOR SMITH. [Not given in 1909–10.]

81. History of Chemistry.—Two hours a week. ½Mj. Winter Quarter, ———.

82. Club meetings.—Meetings will be held twice a month. They may be attended by anyone interested. The subjects for the meetings will be announced at least one week in advance. Summer, Winter, and Spring Quarters.

90–93. Research Work.—This course will include from 30 to 40 hours a week of laboratory work, under the special direction of some one of the instructors in the Department. It is expected that research work for a Doctor's thesis will require 4–6 quarters (4–6 DMj.). Before being admitted to research, a candidate must satisfy the instructors of the Department that his previous training has been sufficient.

90. *Research in Organic Chemistry.*—Autumn, Winter, and Spring Quarters, PROFESSOR NEF.

91. *Research in General Chemistry.*—First Term, Summer Quarter, and Autumn Winter, and Spring Quarters, PROFESSOR SMITH.

92. *Research in Organic and Physico-Organic Chemistry.*—First Term, Summer Quarter, and Autumn, Winter, and Spring Quarters, PROFESSOR STIEGLITZ.

93. *Research in Physical Chemistry.*—Summer, Autumn, and Spring Quarters, ASSOCIATE PROFESSOR MCCOY.

DOCTORS OF PHILOSOPHY OF THE UNIVERSITY OF CHICAGO

MATHEMATICS

1896 John Irwin Hutchinson, Assistant Professor of Mathematics, Cornell University.
On the Reduction of Hyperelliptic Functions ($p=2$) to Elliptic Functions by a Transformation of the Second Degree.

Leonard Eugene Dickson, Associate Professor of Mathematics, The University of Chicago.
The Analytic Representation of Substitutions.

1898 Herbert Ellsworth Slaught, Associate Professor of Mathematics, The University of Chicago.
The Cross-ratio Group of 120 Quadratic Cremona Transformations of the Plane.

1899 John Anthony Miller, Professor of Astronomy, Swarthmore College.
Concerning Certain Elliptic Modular Functions of Square Rank.

1900 Gilbert Ames Bliss, Associate Professor of Mathematics, The University of Chicago.
The Geodesic Lines on the Anchor Ring.

George Lincoln Brown, Professor of Mathematics, South Dakota Agricultural College.
A Ternary Linear Substitution Group of Order 3.360.

William Gillespie, Preceptor in Mathematics, Princeton University.
On the Reduction of Hyperelliptic Integrals ($p=3$) to Elliptic Integrals by Transformation of the Second and Third Degree.

Derrick Norman Lehmer, Assistant Professor of Mathematics, University of California.
Asymptotic Evaluation of Certain Totient Sums.

John Hector McDonald, Assistant Professor of Mathematics, University of California.
On the System of a Binary Cubic and Quadratic and the Reduction of Hyperelliptic Integrals of Genus Two to Elliptic Integrals by a Transformation of the Fourth Order.

Ernest Brown Skinner, Assistant Professor of Mathematics, University of Wisconsin.
Ternary Monomial Substitution Groups of Finite Order with Determinant $\neq 0$.

1901 William Findlay, Professor of Mathematics, McMaster University.
The Sylow Subgroups of the Symmetric Group.

Thomas Milton Putnam, Assistant Professor of Mathematics, University of California.
The Quaternary Linear Homogeneous Group and the Ternary Linear Fractional Group.

1903 Oswald Veblen, Preceptor in Mathematics, Princeton University.
A System of Axioms for Geometry.

1904 William Henry Bussey, Assistant Professor of Mathematics, University of Minnesota.
Generational Relations for the Abstract Group Simply Isomorphic with the Group LF(2; p^n).

1904 HERBERT EDWIN JORDAN, Instructor in Mathematics, Michigan College of Mines.
Group Characters of Various Linear Groups.

ARTHUR WHIPPLE SMITH, Assistant Professor of Mathematics, Colgate University.
Symbolic Treatment of Differential Geometry.

1905 THOMAS EMORY MCKINNEY, Professor of Mathematics, University of North Dakota.
Concerning a Certain Type of Continued Fractions Depending on a Variable Parameter.

ROBERT LEE MOORE, Instructor in Mathematics, Northwestern University.
Sets of Metrical Hypotheses for Geometry.

1906 WILLIAM RAYMOND LONGLEY, Assistant Professor of Mathematics, Yale University.
A Class of Periodic Orbits of an Infinitesimal Body Subject to the Attraction of n Finite Bodies.

ARTHUR RANUM, Instructor in Mathematics, Cornell University.
The Group of Classes of Congruent Matrices with Application to the Group of Isomorphisms of any Abelian Group.

ANTHONY LISPENARD UNDERHILL, Instructor in Mathematics, University of Wisconsin.
Invariants under Point Transformations in the Calculus of Variations.

BUZZ M. WALKER, Professor of Mathematics and Director of School of Engineering, Mississippi Agricultural and Mechanical College.
On the Resolution of Higher Singularities of Algebraic Curves into Ordinary Double Points.

1907 GEORGE DAVID BIRKHOFF, Assistant Professor of Mathematics, Princeton University.
Asymptotic Properties of Certain Ordinary Differential Equations, with Applications to Boundary Value and Expansion Problems.

ROBERT LACEY BÖRGER, Instructor in Mathematics, University of Illinois.
On the Determination of Ternary Linear Groups in the Galois Field of Order p^2.

LOUIS INGOLD, Instructor in Mathematics, University of Missouri.
Vector Interpretation of Symbolic Parameters.

NELS JOHANN LENNES, Instructor in Mathematics, Massachusetts Institute of Technology.
Curves in Non-metrical Analysis Situs with Applications to the Calculus of Variations and Differential Equations.

FREDERICK WILLIAM OWENS, Instructor in Mathematics, Cornell University.
The Introduction of Ideal Elements and Construction of Projective n-space in Terms of a Planar System of Points.

NORMAN RICHARD WILSON, Associate Professor of Mathematics, University of Manitoba.
Isoperimetrical Problems which are Reducible to Non-isoperimetrical Problems.

1908 MARY EMILY SINCLAIR, Instructor in Mathematics, Oberlin College.
On a Compound Discontinuous Solution Connected with the Surface of Revolution of Minimum Area.

1909 ARNOLD DRESDEN, Instructor in Mathematics, The University High School, Chicago, Ill.
The Second Derivatives of the Extremal-integral.

MATHEMATICAL ASTRONOMY

1900 FOREST RAY MOULTON, Associate Professor of Astronomy, The University of Chicago.
Periodic Oscillating Satellites.

1903 William Albert Hamilton, Professor of Astronomy, Beloit College.
The True Radii of Convergence for Expansions as Power Series in the Time, in the Case of Parabolic Motion.

1904 Arthur Constant Lunn, Instructor in Applied Mathematics, The University of Chicago.
The Differential Equations of Dynamics.

1905 Delonzo Tate Wilson, Assistant Professor of Mathematics, Case School of Applied Science.
Work on Minor Planets.

1906 Frank Loxley Griffin, Instructor in Mathematics, Williams College.
Certain Periodic Orbits of k Finite Bodies Revolving About a Relatively Large Central Mass.

1908 William Duncan McMillan, Instructor in Mathematics and Astronomy, The University of Chicago.
Periodic Orbits about an Oblate Spheroid.

PHYSICS

1897 Gordon Ferry Hull, Professor of Physics, Dartmouth College.
On the Use of the Interferometer in the Study of Electric Waves.

Isabel Stone, Principal of American School for Girls, Rome, Italy.
On the Electrical Resistance of Thin Films.

1898 Edwin Sheldon Johounott, Associate Professor of Physics, Rose Polytechnic Institution.
Thickness of the Black Spot on Liquid Films.

1899 Henry Gordon Gale, Assistant Professor of Physics, The University of Chicago.
On the Relation between Density and Index of Refraction of Air.

1900 Robert Francis Ehrhart, Assistant Professor of Physics, Ohio State University.
The Sparkling Potentials between Plates at Small Distances.

1901 Fritz Reichmann, Practical Physicist, Troy, N. Y.
The Capacities of Air Condensers for Very Small Distances between the Plates.

1902 Frank Baldwin Jewett, Electrical Engineer, New York City, N. Y.
A New Method of Determining the Vapor-Density of Metallic Vapors.

1904 Thomas Eaton Doubt, Associate Professor of Physics, Armour Institute of Technology, Chicago, Ill.
The Effect of Intensity Upon the Velocity of Light.

Fannie Cornelia Frisbee (Mrs. Frank B. Jewett), New York City, N. Y.
The Effects of Pressure on Magnetic Induction.

Thomas Carlyle Hebb, Professor of Physics, State Normal School, Marquette, Mich.
The Velocity of Sound.

1905 Frederic Lendhall Bishop, Assistant Professor of Physics, Bradley Polytechnic Institute, Peoria, Ill.
The Thermal Conductivity of Lead.

Glen Moody Hobbs, Secretary of the American School of Correspondence, Chicago, Ill.
The Relation between P.D. and Spark-length for Small Values of the Latter.

Carelton John Lynde, Professor of Physics, MacDonald College, Quebec, Can.
The Effect of Pressure on Surface Tension.

1906 William Richards Blair, Government Observatory, Mt. Weather, Va.
The Change of Phase.

1906 LAWRENCE EMERY GUERNEY, Associate Professor of Physics, University of Idaho.
The Viscocity of Water at Very Low Rates of Shear.

1907 GEORGE WINCHESTER, Professor of Physics, Washington and Jefferson College, Washington, Pa.
Discharge of Electricity from Metals.

OLIVER CHARLES CLIFFORD, Assistant Professor of Physics, Armour Institute of Technology, Chicago, Ill.
Susceptibility of Copper and Tin and Their Alloys.

1909 NEWLAND FARNSWORTH SMITH, Professor of Physics, Olivet College, Olivet, Mich.
Effect of Tension on Thermal and Electrical Conductivity.

WILLIAM ROSS HAM, Professor of Physics, Kenyon College, Gambier, O.
The Polarization of Primary X-Rays.

CHARLES ALBERT PROCTOR, Assistant Professor of Physics, Dartmouth College, Hanover, N. H.
The Variation of $\frac{e}{m}$ with Speed in the Case of Cathode Rays.

CHEMISTRY

1894 ADOLPH BERNHARD, St. Louis High School, St. Louis, Mo.
Ueber die Einführung von Acylen in den Benzoylessigather.

WARREN RUFUS SMITH, Professor of Chemistry, Lewis Institute, Chicago, Ill.
On the Addition Products of the Aromatic Isocyanides.

1896 BERNARD CONRAD HESSE, Consulting Chemist, New York City.
On Malonic Nitrile and Some of its Derivatives.

SAMUEL ELLIS SWARTZ, Professor of Chemistry and Physics, Fairmount College, Wichita, Kan.
The Action of Sodium Ethylate on Amide Bromides.

1897 JAMES BERT GARDNER, Professor of Chemistry, Wabash College, Crawfordsville, Ind.
Condensations with Benzoin by Means of Sodium Ethylate.

LAUDER WILLIAM JONES, Professor of Chemistry, University of Cincinnati.
On Salts of Nitroparaffine and Acylated Derivatives of Hydroxylamine.

1898 FRANK BURNETT DAINS, Professor of Chemistry, Washburn College, Topeka, Kan.
On the Isourea Ethers and Other Derivatives of Ureas.

OTTO FOLIN, Associate Professor of Biological Chemistry, Harvard Medical School, Boston, Mass.
On Urethanes.

ELIZABETH JEFFREYS, Professor of Chemistry, Pritchett College, Glasgow, Mo.
On Undecylamine and Pentadecylamine and the Preparation of the Higher Amines of the Alipathic Series.

HERBERT NEWBY MCCOY, Associate Professor of Chemistry, The University of Chicago, Chicago, Ill.
On the Hydrochlorides of Carbo-phenylimido Derivatives.

1899 JOHN CHARLES HESSLER, Professor of Chemistry, James Millikin University, Decatur, Ill.
On Alkyl Malonic Nitriles and Their Derivatives.

WILLIAM MCPHERSON, Professor of Chemistry, Ohio State University, Columbus, O.
On the Nature of the Oxyazo Compounds.

JAMES HARVEY RANSOM, Professor of General Chemistry, Purdue University, Lafayette, Ind.
On the Molecular Rearrangement of o-Aninophenylethyl Carbonate to o-Oxyphenylurethane.

1900 HENRY CHALMERS BIDDLE, Associate Professor of Chemistry, University of California.
Ueber Derivate des Isuretins der Formhydroxamsäure und ihre Beziehungen zur Knallsäure.

1901 RALPH HARPER MCKEE, Professor of Chemistry, Lake Forest University, Lake Forest, Ill.
On the Oxygen Ethers of the Ureas: Methyl- and Ethylisourea.

1902 SOLOMON FARLEY ACREE, Associate Professor of Chemistry, Johns Hopkins University, Baltimore, Md.
On Sodium Phenyl and the Action of Sodium on Ketones.

WALLACE APPLETON BEATTY, ———.
The Action of Carbon Monoxide on Sodium Alcoholates Alone and in the Presence of Salts of Fatty Acids.

EUGENE PAUL SCHOCH, Assistant Professor of Chemistry, University of Texas, Austin, Tex.
The Red and the Yellow Mercuric Oxides and the Mercuric Oxychlorides.

EDWIN EMERY SLOSSON, Literary Editor of *The Independent*, New York City.
On Acylhalogenamine Derivatives and the Beckmann Rearrangement.

1903 HENRY TABOR UPSON, Vice-President and Manager of Pease Oil Co., Buffalo, N. Y.
The Molecular Rearrangement of Aminophenylalkyl Carbonates.

1904 MAXWELL ADAMS, Professor of Chemistry, State University, Reno, Nev.
On Some Hydroxylamine Compounds.

RAYMOND FOSS BACON, Government Chemist, Bureau of Science, Manila, P. I.
On the Reactions of Sodium Benzhydrol.

WILLIAM MCAFEE BRUCE, Arkansas Agricultural College.
On the Oxygen Ethers of Urea.

NELLIE ESTHER GOLDTHWAITE, Research Assistant, University of Illinois, Champaign, Ill.
On Substituted Benzhydrol Derivatives and Bromcyanacetic Ether.

OSWIN W. WILLCOX, Assistant Chemist, United States Smokeless Powder Works, Dover, N. J.
On the Reaction of Ethyl Chlorsulphonate.

1905 WILLIAM LLOYD EVANS, Assistant Professor of Chemistry, Ohio State University, Columbus, O.
On the Behavior of Benzoyl Carbinol towards Alkalies and Oxidizing Agents.

WILLIAM MCCRACKEN, Professor of Natural Sciences, State Normal School, Kalamazoo, Mich.
Study in Catalysis. V. The Catalysis of Imidoesters.

HERMANN SCHLESINGER, Associate in Chemistry, The University of Chicago.
Studies in Catalysis. VI. The Catalysis of Imidoesters.

1906 ROY HUTCHINSON BROWNLEE, Assistant Superintendent, Standard Oil Co., Whiting, Ind.
On Precipitated Sulphur.

CHARLES M. CARSON, Professor of Chemistry, University of New Brunswick.
On Amorphous Sulphur: Further Study of the Two Forms of Liquid Sulphur as Dynamic Isomers.

HENRY MAX GOETTSCH, Research Chemist, Mallinchrodt Chemical Works, St. Louis, Mo.
The Absorption Coefficients of Uranium Compounds.

WILLIS STOSE HILPERT, Chemist, American Medical Association, Chicago, Ill.
Stereoisomeric Chlorimido Acid Esters.

1906 James Wright Lawrie, Chemist, International Harvester Co., Chicago, Ill.
The Chemistry of the Acetylidene Compounds.

Andrew Fridley McLeod, Instructor in Chemistry, The University of Chicago.
On Aldol, Pentaerythrose, and the Action of Copper Acetate on the Hexoses.

1907 Edith Ethel Barnard, Instructor in Chemistry, The University of Chicago.
The Catalysis of Imidoesters as Affected by the Presence of Non-electrolytes and Electrolytes.

Katherine Blunt, Instructor in Chemistry, Vassar College, Poughkeepsie, N. Y.
The Formation of Amidines.

Willey Denis, Assistant Chemist, United States Department of Agriculture, Washington, D. C.
On the Behavior of Various Aldehydes, Ketones, and Alcohols Toward Oxidizing Agents.

Robert Anderson Hall, Professor of Chemistry, Clemson College, South Carolina.
The Action of Ammonia on Isourea Esters.

Louis Allen Higley, Chemist, Kennicott Walter Softening Works, Chicago Heights, Ill.
On the Behavior of Sodium and Sodium Alcoholates toward Various Esters.

William Horace Ross, Assistant Chemist, Agricultural Experiment Station, University of Arizona, Tucson, Ariz.
On the Relation Between the Radio-activity and the Composition of Thorium and Uranium Minerals.

Louis A. Test, Professor of Chemistry, Occidental College, Los Angeles, Cal.
The Rearrangement of o-Amino Phenyl Esters.

1908 George Cromwell Ashman, Professor of Chemistry, Bradley Institute, Peoria, Ill.
Studies in Radioactivity.

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1911/12

The University of Chicago

FOUNDED BY JOHN D. ROCKEFELLER

CIRCULAR OF THE DEPARTMENTS OF

MATHEMATICS, ASTRONOMY AND ASTROPHYSICS, PHYSICS CHEMISTRY

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1911

CALENDAR FOR THE YEAR 1911–12

1911

June 9	Friday	Junior College Day
June 11	Sunday	Convocation Sunday
June 12	Monday	Class Day Summer Meeting of University Congregation
June 13	Tuesday	Summer Convocation Alumni Day
June 14	Wednesday	Quarterly Examinations
June 15	Thursday	
June 16	Friday	
June 16	Friday	Spring Quarter ends
June 19	*Monday*	*Summer Quarter begins*
July 4	Tuesday	Independence Day: a holiday
July 26	Wednesday	Examinations for First Term of Summer Quarter First Term of Summer Quarter ends
July 27	Thursday	Second Term of Summer Quarter begins
Aug. 27	Sunday	Convocation Sunday
Sept. 1	Friday	Examinations for Second Term of Summer Quarter Autumn Convocation Second Term of Summer Quarter ends
Oct. 2	*Monday*	*Autumn Quarter begins*
Nov. 30	Thursday	Thanksgiving Day: a holiday
Dec. 17	Sunday	Convocation Sunday
Dec. 19	Tuesday	Winter Convocation
Dec. 20	Wednesday	Quarterly Examinations
Dec. 21	Thursday	
Dec. 22	Friday	
Dec. 22	Friday	Autumn Quarter ends

1912

Jan. 2	*Tuesday*	*Winter Quarter begins* Matriculation and Registration of incoming students
Feb. 12	Monday	Lincoln's Birthday: a holiday
Feb. 22	Thursday	Washington's Birthday: a holiday
Mar. 17	Sunday	Convocation Sunday
Mar. 19	Tuesday	Spring Convocation
Mar. 20	Wednesday	Quarterly Examinations
Mar. 21	Thursday	
Mar. 22	Friday	
Mar. 22	Friday	Winter Quarter ends
Mar. 22—April 1		Quarterly Recess
Apr. 1	*Monday*	*Spring Quarter begins* Matriculation and Registration of incoming students
May 30	Thursday	Memorial Day: a holiday
June 7	Friday	Junior College Day
June 9	Sunday	Convocation Sunday
June 10	Monday	Class Day Summer Meeting of University Congregation
June 11	Tuesday	Summer Convocation Alumni Day
June 12	Wednesday	Quarterly Examinations
June 13	Thursday	
June 14	Friday	
June 14	Friday	Spring Quarter ends

GENERAL INFORMATION

The Organization of the University includes: the Graduate School of Arts and Literature; the Ogden (Graduate) School of Science; the Colleges (Senior, last two years; and Junior, first two years) of Arts, Literature, and Science; the Divinity School; the Law School; Courses in Medicine; the College of Education; the College of Commerce and Administration; the College of Religious and Social Science.

Faculty and Equipment.—The faculty numbers three hundred and thirty; the libraries contain 325,525 volumes. The University owns ninety acres of land in Chicago and has thirty-five buildings.

Location of the University.—The University grounds lie on both sides of the Midway Plaisance between Washington and Jackson Parks, six miles south of the center of Chicago. Electric cars, elevated trains, and the Illinois Central suburban service reach all railway stations. Baggage and mail service is provided at the Information Office in Cobb Lecture Hall.

The University Year is divided into quarters: the Autumn (October to December); the Winter (January to March); the Spring (April to the middle of June); the Summer (middle of June to August). For the year 1911–12 the exact dates for the opening of the four quarters are: Summer Quarter, June 19, 1911; Autumn Quarter, October 2; Winter Quarter, January 2, 1912; Spring Quarter, April 1, 1912. Students are admitted at the opening of each quarter; graduation exercises are held at the close of each quarter.

The Unit of Work and of Credit is a *major*, i.e., a course of instruction involving four or five recitations or lecture hours per week for a full quarter, or double that number of hours for a term of six weeks. A *minor* is one-half a major. Normal work is three majors per quarter, or nine majors per year of three quarters.

Degrees.—The University confers in the Graduate Schools the degrees of Doctor of Philosophy and of Master of Arts and of Science; in the Colleges, the degrees of Bachelor of Arts, of Science, of Philosophy; in the Divinity School, the degrees of Bachelor of Divinity, Master of Arts, and Doctor of Philosophy; in the Law School, the degrees of Doctor of Law and Bachelor of Laws; in the School of Education, the degrees of Bachelor of Arts in Education, of Philosophy in Education, and of Science in Education.

Tuition, Fees, etc.—The regular fee for three majors in Arts, Literature, and Science, and in the College of Education is $40 per quarter. In Law and Medicine, the fees are $50 and $60, respectively. All students pay once a matriculation fee of $5. Laboratory fees vary from $2.50 to $5 per major per quarter.

Cost of Living.—In University dormitories, rooms rent from $20 to $74 per

quarter. Table board in the women's halls is $4.50 per week. At Hutchinson Hall (à la carte service) board costs from $3.50 per week upward. Board and lodging may be had at the same or even lower rates outside the University.

Fellowships, Scholarships, Student Service, etc.—By virtue of endowments, and special appropriations, fellowships, scholarships, and service afford stipends or tuition to a number of able and deserving students. The University also maintains a Bureau for securing outside employment.

OFFICERS OF ADMINISTRATION

HARRY PRATT JUDSON, President of the University, Haskell Museum, Room 10.

ALONZO KETCHAM PARKER, University Recorder, Cobb Lecture Hall, Room 2A3.

CHARLES RICHMOND HENDERSON, University Chaplain, Cobb Lecture Hall, Room 1.

THOMAS WAKEFIELD GOODSPEED, University Registrar, The Press Building, First Floor.

DAVID ALLAN ROBERTSON, Secretary to the President, Haskell Museum, Room 10.

JAMES ROWLAND ANGELL, Dean of the Faculties of Arts, Literature, and Science, Cobb Lecture Hall, Room 2A4.

ALBION WOODBURY SMALL, Dean of the Graduate School of Arts and Literature, Cobb Lecture Hall, Room 2A4.

ROLLIN D. SALISBURY, Dean of the Ogden (Graduate) School of Science, Cobb Lecture Hall, Room 2A4.

MARION TALBOT, Dean of Women, Cobb Lecture Hall, Room 2A1.

LEON CARROLL MARSHALL, Dean of the Senior Colleges and Dean of the College of Commerce and Administration, Cobb Lecture Hall, Room 2A6.

ROBERT MORSS LOVETT, Dean of the Junior Colleges, Cobb Lecture Hall, First Floor, Room 2A7.

JAMES WEBER LINN, HENRY GORDON GALE, Ellis Hall; MARION TALBOT, ELIZABETH WALLACE, Lexington Hall: Deans in the Junior Colleges.

SOPHONISBA PRESTON BRECKINRIDGE, Assistant Dean of Women, Lexington Hall.

NATHANIEL BUTLER, Examiner for Affiliations, Cobb Lecture Hall, Room 8.

FRANK JUSTUS MILLER, Examiner for Secondary Schools, Cobb Lecture Hall, Room 8.

MATHEMATICS, ASTRONOMY AND ASTROPHYSICS, PHYSICS, AND CHEMISTRY

FACILITIES

The equipment of each department will be referred to in the pages which follow, but it may be said for all, that the equipment is adequate for effective instruction and research in all lines in which work is offered. The Departmental Libraries contain files of the more important periodicals relating to these sciences, and most of the treatises and special publications necessary for research work.

DEGREES

Graduate study may lead to the degree of Master of Arts, of Philosophy, or of Science, or to the degree of Doctor of Philosophy under the conditions specified below.

The Master's degrees.—Two Master's degrees are conferred, viz.: Master of Arts and Master of Science, depending upon the baccalaureate degree. These degrees are conferred only for work done in residence at the University of Chicago. The minimum residence requirement is three full quarters, following a Bachelor's degree equivalent to that of the University of Chicago. The work need not be all in one department, but it must be selected according to some rational plan, approved by the candidate's Dean and the departments in which the work is taken. A dissertation is also required.

The degree of Doctor of Philosophy.—The Doctor's degree is conferred only after three years of satisfactory graduate work, following a Bachelor's degree equivalent to that of the University of Chicago. The work for this degree is in two or three departments, with a dissertation in the principal one.

FELLOWSHIPS AND SCHOLARSHIPS

The Trustees award annually about seventy fellowships in the Graduate Schools. These fellowships range in value from $120, the tuition fees of a student for three quarters, to $400, in addition to the tuition fees for three quarters. A limited number of scholarships, covering a part or all of the tuition fees for three quarters, are also awarded annually.

Full particulars concerning higher degrees, fellowships, scholarships, and other matters of interest to graduate students will be found in the Circular of Information of the Graduate Schools, which will be sent upon application.

MATHEMATICS

OFFICERS OF INSTRUCTION

ELIAKIM HASTINGS MOORE, PH.D., LL.D., SC.D., MATH. D., Professor and Head of the Department of Mathematics.

OSKAR BOLZA, PH.D., Non-Resident Professor of Mathematics (Freiburg i. B).

GEORGE WILLIAM MYERS, PH.D., Professor of the Teaching of Mathematics and Astronomy, the School of Education.

LEONARD EUGENE DICKSON, PH.D., Professor of Mathematics.

HERBERT ELLSWORTH SLAUGHT, PH.D., Associate Professor of Mathematics.

JACOB WILLIAM ALBERT YOUNG, PH.D., Associate Professor of the Pedagogy of Mathematics.

GILBERT AMES BLISS, PH.D., Associate Professor of Mathematics.

ERNEST JULIUS WILCZYNSKI, PH.D., Associate Professor of Mathematics.

WILLIAM HOOVER, PH.D., Non-Resident University Extension Assistant Professor of Mathematics (Athens, Ohio).

ARTHUR CONSTANT LUNN, PH.D., Assistant Professor of Applied Mathematics.

JOHN WESLEY YOUNG, PH.D., Professor and Head of the Department of Mathematics, University of Kansas (Summer Quarter, 1911).

HANS FREDERIK BLICHFELDT, PH.D., Associate Professor of Mathematics, Leland Stanford Jr. University (Summer Quarter, 1911).

FELLOWS, 1911–12

EDWARD WILSON CHITTENDEN, A.B.

CHARLES ALBERT FISCHER, A.B.

ELTON JAMES MOULTON, S.B., S.M.

MILDRED LEONORA SANDERSON, A.B.

GENERAL STATEMENT

The regular Junior College courses are courses 1, 2, 3, 7, and 15. Students of the College of Science and of the College of Arts are required to take course 1.

Students who expect to specialize in Mathematics, Astronomy, or Physics should confer with the instructors in Mathematics in planning their courses. They should take courses 1, 2, 3, 18, 19, and 20. It is possible, however, for students of exceptional ability in Mathematics to pass from course 2 to course 18, if course 3 is taken at the same time as course 18. Students who desire to have at least a glimpse beyond the elements of Mathematics should elect courses 3 and 15.

The following courses introductory to the higher Mathematics are intended

both (1) for students making Mathematics their principal subject, and (2) for those making Mathematics their secondary subject, in particular for students of Astronomy and Physics: (A) †Differential and integral calculus (3Mj); (B) †Solid analytics; theory of equations; determinants and elementary invariants; (C) †Analytic mechanics (2Mj); vector analysis; advanced mechanics (2Mj); theory of the potential; (D) †Advanced calculus, †differential equations, †theory of definite integrals, †elliptic integrals, elements of the theory of functions; (E) Synthetic projective geometry; analytic projective geometry; differential metric geometry; differential projective geometry; (F) Theory of numbers; theory of invariants; selected chapters of algebra; theory of substitutions with applications to algebraic equations; quaternions.

Groups (A)–(F) indicate six sequences of courses running through the usual academic year from October to June. These sequences vary slightly from year to year, the courses marked (†) are given annually, and the other courses usually once in two years.

The undergraduate student who wishes to specialize in Mathematics should take courses of group (A) as Junior College Electives, of (B) in his first Senior College year, and of (C) and (D) in his second Senior College year.

The courses of groups (A)–(F) and the special courses in the higher Mathematics are intended to give the graduate student a comprehensive view of modern Mathematics, to develop him to scientific maturity, and to enable him to follow, without further guidance, the scientific movement of the day in Mathematics, and, if possible, to take an active part in it by creative research. The special and research courses vary from year to year. They may be classified, in general, as relating to (*a*) Algebra and Arithmetic; (*b*) Analysis; (*c*) Geometry; (*d*) Mechanics and Applied Mathematics; and (*e*) the Foundations and Interrelations of the Mathematical Disciplines as purely abstract deductive systems. Attention is called to courses of type (*d*) offered by the Departments of Astronomy and Physics.

The proper arrangement of courses is a matter of extreme importance; the best arrangement for any student depends on his previous mathematical studies, and should be determined by conference with some member of the Department.

The courses of the Summer Quarter are designed to meet the needs of those college men and others wishing to study advanced Mathematics, who are able to spend only the summer in residence. The courses of a series of four summer quarters are arranged so as to give a wide view of modern Mathematics.

Scholarship examinations.—The competitive examinations for the Senior College Scholarship and for the Graduate Scholarship in Mathematics are held each Spring Quarter at times and places announced in the *Weekly Calendar*. Prospective candidates should confer with the Departmental Examiner in Mathematics. Files of papers set at previous Scholarship examinations are accessible in the Departmental Library. Candidates for the Senior College Scholarship will be examined on courses 1, 2, and 3; those for the Graduate Scholarship on courses 18, 19, 20, 31, 32, 47, 48, and 49.

Models.—A collection of Brill's models: plaster and thread models of quadric surfaces, plaster models of cubic and Kummer's quartic surfaces, models of cyclides and surfaces of constant positive and negative curvature, and thread models of three-dimensional projections of four-dimensional regular bodies.

MATHEMATICAL CLUBS

The Departmental Club meets regularly for the review of memoirs and books, and for the presentation of results of research. The club is conducted by the members of the faculties of Mathematics and Mathematical Astronomy. Graduate students of the departments are expected to attend and otherwise to participate in the meetings of the club.

The Junior Mathematical Club, with fortnightly meetings, is conducted by the graduate students of the departments.

HIGHER DEGREES

Master's degree.—Candidates for the Master's degree in Mathematics are expected to offer for examination eight courses in advance of course 20, and to present a satisfactory thesis on an assigned topic closely related to one of these subjects.

Degree of Doctor of Philosophy.—Candidates for the Doctor's degree with Mathematics as secondary subject are expected to offer for examination courses 18, 19, 20, and six courses in advance of course 20.

Candidates for the Doctor's degree with Mathematics as principal subject are expected (1) to offer for examination the subjects covered by fifteen majors of initial courses of groups (A)–(F), and by a considerable body of special courses, in each case presumably most closely related to the subject of the doctoral dissertation, and (2) to present a dissertation, in finished form, embodying valuable results of mathematical inquiry. The subject of the dissertation may be a topic of pure or applied mathematics or of the history, philosophy, or pedagogy of mathematics.

PREPARATION FOR TEACHING

Courses in the history and the teaching of Elementary Mathematics—Arithmetic, Algebra, Geometry, Trigonometry, Analytic Geometry, Calculus, Mechanics—are offered by this Department and the School of Education. These courses embody the conviction that elementary students need to have their Mathematics made, not easier, but more perfectly intelligible and attractive. To this end it is believed that teachers should more generally appreciate and utilize in instruction the unity of Mathematics, as made up of various closely interrelated parts, and the character of Mathematics, as an ideal science developed by abstraction from various more concrete domains.

A) *Secondary-school positions.*—Students who expect to teach mathematics as a major subject in secondary schools should complete at least the following courses in their undergraduate career. (1) Courses in pure mathematics: Trigonometry, College Algebra, Plane Analytic Geometry, Introductory

Calculus and Applications of Calculus (three majors), Theory of Equations, and the Synoptic course; (2) Courses in applied mathematics: Descriptive Astronomy, Mechanics, and General Physics; (3) The two courses, Principles of Education and Methods of Education, which may be taken either in the Junior College or in the Senior College; (4) Practice teaching in mathematics in the University High School, for which the above courses in education are prerequisite; (5) A course in the Teaching of Secondary Mathematics and a course in the History of Secondary Mathematics.

B) *Minor collegiate positions.*—Those who look forward to teaching mathematics in normal schools and small colleges should as undergraduates complete at least the following courses: (1) The general courses in education and those in the history and teaching of mathematics mentioned in (3) and (5) above. (2) The content courses specified in (1) and (2) above, together with Advanced Calculus (3 majors) and Solid Analytic Geometry.

Candidates for these positions should take at least one year of graduate work leading to the Master's degree in mathematics and during this year should visit some of the college courses in mathematics with the purpose of observing methods of teaching. It is the intention of the Department to offer such candidates opportunity, as far as possible, to act as assistants in connection with the collegiate classes, in order that they may gain experience through both observation and practice.

C) *University positions.*—Candidates for university positions should qualify for the Doctor's degree. Courses in the history of mathematics and in the principles and practice of education are strongly recommended.

COURSES OF INSTRUCTION

Junior College Courses

0. Solid Geometry.—An elementary course based upon entrance Algebra and Plane Geometry. [Not given in 1911–12.]

Note.—Students from accredited preparatory schools may present themselves for examination in this subject *at the University* for college credit.

1. Plane Trigonometry.—Mj. Summer Quarter, Mr. Reaves; Autumn Quarter, 3 sections, Associate Professors Bliss and Wilczynski, and Mr. ———; Winter Quarter, 2 sections, Professors Myers and Associate Professor Slaught; Spring Quarter, 2 sections, Associate Professor Young and Mr. ———.

2. College Algebra.—Prerequisite: course 1. Mj. Summer Quarter, Associate Professor Blichfeldt; Autumn Quarter, Associate Professor Wilczynski; Winter Quarter, Dr. MacMillan; Spring Quarter, Professor Myers.

3. Analytic Geometry.—Elements of plane analytics, including the geometry of the conic sections, with an introduction to solid analytics. Prerequisite: courses 1 and 2. Mj. Summer Quarter, Professor J. W. Young; Autumn Quarter, Associate Professor Slaught; Winter Quarter, Associate Professor Wilczynski; Spring Quarter, Associate Professor Bliss.

7. Elementary Mechanics.—Without the use of Calculus. Prerequisite: course 1. Mj. Assistant Professor Lunn. [Not given in 1911–12.]

15. Introductory Calculus.—The elementary fundamental principles, methods, and formulas of differential and integral calculus will be carefully studied in connec-

tion with simple problems of geometry and the physical sciences. This course is intended primarily for those who do not wish to take the longer course in Calculus (courses 18, 19, and 20). Prerequisite: courses 1 and 2. Mj. Spring Quarter, Associate Professor Young.

Senior College Courses

18, 19. Calculus I, II.—A development of the three fundamental notions of the Calculus, the derivative, anti-derivative, and the definite integral, with especial emphasis on their geometrical interpretations and their relations to problems in Geometry, Mechanics, and Physics. Prerequisite: courses 1, 2, and 3. Two consecutive majors. Autumn and Winter Quarters, Professor Dickson; Winter and Spring Quarters, Associate Professors Slaught and Wilczynski.

18. Calculus I: Differential Calculus.—A graphic study of rational algebraic functions and of certain simple irrational transcendental functions, yielding material for a geometric introduction to the fundamental notions and processes of the Calculus. Prerequisite: courses 1, 2, and 3. Mj. Summer Quarter, Associate Professor Young.

19. Calculus II: Integral Calculus.—A course aimed at a comprehension of the nature of integration and of its applications to Geometry and Physics; solution of numerous problems; use of table of integrals. Prerequisite: course 18. Mj. Summer Quarter, Associate Professor Blichfeldt.

20. Applications of the Calculus.—Partial differentiation and multiple integrals. Elements of the theory of Differential Equations and applications of the Calculus to Mechanics. Introduction to Differential Geometry in the plane and in space. Prerequisite: courses 18 and 19. Mj. Spring Quarter, Dr. Lunn.

25. Graphical Methods in Algebra (For Teachers).—The cross section paper as a mathematical instrument. M. Professor Moore. [Not given in 1911–12.]

31. Solid Analytics.—Prerequisite: courses 3 and 18. Mj. Summer Quarter, Professor J. W. Young.

32. Theory of Equations.—Prerequisite: courses 18 and 19. Winter Quarter, Associate Professor Young.

33. Determinants and Elementary Invariants.—Determinants may be taken as a minor for the first term. Prerequisite: course 32. Mj. Spring Quarter. [Not given in 1911–12.]

34. Limits and Series.—Critical theory of convergence of sequences and series of numbers. Sequences and series of functions; uniformity of convergence. Prerequisite: course 18. Mj. [Not given in 1911–12.]

35. The Teaching of Elementary School Mathematics.—(School of Education: Mathematics 1.) Mj. Winter Quarter, Associate Professor Young.

36. The Teaching of Secondary Mathematics.—(School of Education: Mathematics 2.) Mj. Spring Quarter, Associate Professor Young.

37. Critical Review of Secondary Mathematics.—A brief survey of the subject-matter of Secondary Mathematics from the modern point of view, aiming both to organize the theory of the whole scientifically and to gather the products of this work for use in teaching. Primarily for teachers, actual and prospective, but open also to others. Mj. Summer Quarter, Associate Professor Young.

38. Synoptic Course in Advanced Mathematics.—A general historical and logical survey of a considerable portion of pure and applied mathematics. Prerequisite: courses 1, 2, and 3. Associate Professor Wilczynski. [Not given in 1911–12.]

46. Advanced Calculus.—Selected topics in the Differential and Integral Calculus requiring more extensive and theoretical treatment than is given in courses 18 and 19: for example, development of the formulas for successive differentiation and the differentiation of implicit functions, Taylor's formula with applications, transformation of variables in differential equations and multiple integrals, line inte-

grals and partial integration of multiple integrals, applications of the Calculus to the theory of probability. Prerequisite: courses 18 and 19. Mj. Autumn Quarter, ASSISTANT PROFESSOR LUNN.

47. Differential Equations.—A study of the more common types of ordinary differential equations, especially those of the first and second orders, with emphasis on geometrical interpretations and applications to geometry, elementary mechanics, and physics. Prerequisite: courses 18, 19, and preferably 20. Mj. Autumn Quarter, ASSOCIATE PROFESSOR SLAUGHT.

48. Elliptic Integrals.—A systematic development of the theory of indefinite integration, leading to elliptic integrals and the elements of elliptic functions, with attention to problems and applications. This course includes also an introduction to Fourier series. Prerequisite: courses 18, 19, 20, and preferably 46 or 47. Mj. Summer and Winter Quarters, ASSOCIATE PROFESSOR BLISS.

49. Theory of Definite Integrals.—A course treating of the properties and methods of computing definite integrals, including a study of methods of approximation, improper definite integrals, Eulerian integrals, multiple integrals, with many problems and applications. The course may at times be supplemented by an introduction to Bessel's functions. Prerequisite: courses 47 and 48. Mj. Spring Quarter, ASSOCIATE PROFESSOR BLISS.

GRADUATE COURSES

NOTE.—Students should register for graduate courses only after consultation with instructors.

65A, B, C, D. Reading and Research in Pure Mathematics.—When in the judgment of the Department it is advisable that students undertake definite mathematical reading and research not closely connected with any current lecture course or seminar, this work will be directed by PROFESSORS MOORE AND DICKSON, ASSOCIATE PROFESSOR BLISS, OR ASSOCIATE PROFESSOR WILCZYNSKI. Mj. or DMj. Each Quarter.

66A, B, C. Reading and Research in Applied Mathematics.—Advisable reading and research will be directed by PROFESSOR MOORE, PROFESSOR MYERS, OR ASSISTANT PROFESSOR LUNN. Mj. or DMj. Each Quarter.

71A, B. Theory of Numbers: A, Theory of Congruences; B, Theory of Algebraic Numbers.—Introductory courses, the second presupposing the first. A: M. First Term; B: M. Second Term, PROFESSOR DICKSON. [Not given in 1911–12.]

74. Theory of Algebraic Numbers.—In particular, Hensel's exhibition of analogies with Weierstrass' theory of Functions. Mj. PROFESSOR MOORE. [Not given in 1911–12.]

81. Substitution Groups and Algebraic Equations.— An introduction to the theory of groups of substitutions, with application to the Galois theory of algebraic equations. Mj. PROFESSOR DICKSON. [Not given in 1911–12.]

82. Finite Groups.—Elements of the theory of abstract groups; selected topics on substitution groups, rotation groups, and congruence groups. Mj. Professor DICKSON. [Not given in 1911–12.]

83. Finite Collineation-Groups.—General theory of reducibility of matrices and of linear groups. Complete enumeration of collineation-groups in a given number of variables: the methods of Klein, Gordan, Jordan, Valentiner, and Blichfeldt, with special reference to the ternary and quaternary groups. Examples of advances made in abstract group theory and in permutation-groups by the study of collineation-groups; theorems by Frobenius and Burnside. Prerequisite: A knowledge of the elements of determinants and group theory. Mj. Summer Quarter, ASSOCIATE PROFESSOR BLICHFELDT.

84. Continuous Groups.—An illumination of the fundamental concepts and theorems of the Lie theory in connection with various classes of problems of geometry. PROFESSOR DICKSON. [Not given in 1911–12.]

91. Introduction to Modern Higher Algebra.—Based on Bôcher's *Introduction to Higher Algebra.* Mj. Autumn Quarter, PROFESSOR DICKSON.

94. Theory of Invariants.—The theory of binary quantics, with applications to the theory of equations and to geometry. Prerequisite: course 91. Mj. Winter Quarter, PROFESSOR DICKSON.

95. Quadratic Forms.—The theory of Weierstrass, Kronecker, and Frobenius, with extension to a general domain of rationality. Mj. PROFESSOR DICKSON. [Not given in 1911–12.]

98. General Algebra.—While special attention will be given to linear associative algebra, particularly to quaternions, various other types of linear and non-linear algebras will be considered, in particular those in which division is always possible. Mj. PROFESSOR DICKSON. [Not given in 1911–12.]

102. Fundamental Existence Theorems in Analysis.—A study of the existence theorems for implicit functions, ordinary and partial differential equations, and their applications in Analysis. Mj. Spring Quarter, ASSOCIATE PROFESSOR BLISS.

104. Calculus of Variations.—A study of Euler's differential equation for various types of problems, with a discussion of the further conditions of the theory in the simpler cases. Prerequisite: a good knowledge of the elements of the theory of functions of real variables. Mj. Summer Quarter, ASSOCIATE PROFESSOR BLISS.

106. Partial Differential Equations.—The geometrical theory of equations of the first order. Linear equations. Systems of equations of the first order. Introduction to equations of the second order. Applications to geometry and physics. Mj. ASSOCIATE PROFESSOR BLISS. [Not given in 1911–12.]

108. Differential Equations from the Standpoint of Lie.—The relations between continuous groups and differential equations. The Picard-Vessiot theory of linear differential equations. Mj. [Not given in 1911–12.]

109A. Integral Equations.—Introduction to the theory of integral equations and their applications. M. Summer Quarter, First Term, PROFESSOR MOORE.

112. Introduction to General Analysis, I, II, III.—Based on Moore's *Introduction to a Form of General Analysis.* The general analysis in question is the theory of systems of classes of functions, functional operations, etc., involving at least one general variable on a general range. A general variable is a variable entering the theory without direct characterization as to quality or range of variation. A real—and single—valued function ξ of a general variable p has as especially important particular instances: (I) a real number ξ, the variable p having only one value; (II) an n-partite real number $\xi=(\xi_1, \ldots, \xi_n)$, or point ξ in real space of n dimensions, the variable p having the values $p=1, 2, \ldots, n$; (III) an infinite sequence $\xi=(\xi_1, \xi_2, \ldots, \xi_n, \ldots)$ of real numbers, the variable p having the values $p=1, 2, \ldots, n, \ldots$; (IV) a function ξ or $\xi(p)$ of the variable p on the linear interval $0 \leqq p \leqq 1$ of the real number system. The first part of this introductory course considers certain fundamental closure and dominance properties of classes of functions of a general variable, properties possessed in particular by the class: (I) of all real numbers; (II) of all n-partite real numbers; (III_0) of all numerical sequences converging to zero; (III_1) of all absolutely convergent series of real numbers; (IV) of all continuous functions of p on the interval $0 \leqq p \leqq 1$. The second part of the introductory course considers certain fundamental properties of classes of functions of several independent variables, of which one is general, properties connected with the composition of classes of functions of distinct variables. The course presupposes a knowledge of the elements of the theory of functions of real variables, and is intended to lead to independent investigations in various chapters of general analysis. Prerequisite: course 48 and a certain general mathematical maturity. Mj. Winter Quarter, PROFESSOR MOORE.

112A. Introduction to General Analysis.—Based on Moore's *Introduction to a Form of General Analysis.* Prerequisite: course 48 and a certain general mathematical maturity. M. Summer Quarter, First Term, PROFESSOR MOORE.

113. Theory of Functions of Infinitely Many Variables.—A survey of the recent work of D. Hilbert, E. Schmidt, and others, with applications to differential and integral equations. Prerequisite: course 48 and a certain general mathematical maturity. Mj. PROFESSOR MOORE. [Not given in 1911–12.]

114. Differential Equations in General Analysis.—Geometry in a function-space. Determination of functions of a real variable t and a general variable p which satisfy a differential equation with respect to t. Prerequisite: course 112. Mj. Spring Quarter, PROFESSOR MOORE.

115. Integral Equations in General Analysis.—A development of the theory of Fredholm, Hilbert, and others in the sense of General Analysis. Prerequisite: course 112. Mj. PROFESSOR MOORE. [Not given in 1911–12.]

121. Theory of Functions of a Complex Variable.—Introduction to the algebra and calculus of complex numbers and their geometric representation; conform representation. The theory of power series and the properties of analytic functions. Introduction to the theory of algebraic functions. Prerequisite: courses 47 and 48. Mj. Autumn Quarter, ASSOCIATE PROFESSOR BLISS.

122. Algebraic Functions.—The elements of the theory of algebraic functions and their integrals, with applications to the theory of elliptic functions. Prerequisite: course 121. Mj. Winter Quarter, ASSOCIATE PROFESSOR BLISS.

123. Elliptic Functions.—Elliptic integrals and the Weierstrassian theory of elliptic functions. Applications of elliptic functions. Mj. [Not given in 1911–12.]

126. Linear Differential Equations.—From the standpoint of the theory of analytic functions. The general theory illustrated particularly by equations of the second order. Special study of the hypergeometric functions. Prerequisite: course 121 or 122. Mj. [Not given in 1911–12.]

127. Modern Theories of Analytic Differential Equations with Applications to Celestial Mechanics.—Properties of solutions of general system of the nth order as functions of independent variable, of parameters, of initial values of dependent variables. Solutions developed as power series in independent variable, in parameters and initial values of dependent variables, by the Cauchy-Lipschitz process, by the Picard approximation process, by continued variation of parameters. Application to elliptic and hyperelliptic functions and periodic solutions of problem of three bodies. Linear equations with applications to hypergeometric functions. Linear equations with periodic coefficients. Prerequisite: course 121. Two consecutive majors. Winter and Spring Quarters, ASSOCIATE PROFESSOR MOULTON.

131. Synthetic Projective Geometry.—Determination of fundamental postulates; theory of one dimensional systems of the first and second orders. Mj. Summer Quarter, PROFESSOR J. W. YOUNG.

141. Analytic Projective Geometry.—The co-ordinate system of Analytic Projective Geometry. The principle of duality. The projective theory of conic sections. Introduction to the geometry of space. Mj. ASSOCIATE PROFESSOR BLISS. [Not given in 1911–12.]

142. Higher Plane Curves.—General properties of algebraic curves. Special study of the curves of the third and fourth order. Prerequisite: course 141. [Not given in 1911–12.]

144. Line Geometry.—The line co-ordinates of Plücker and Klein. Complexes, congruences, and ruled surfaces. Prerequisite: course 31. Mj. Spring Quarter, ASSOCIATE PROFESSOR WILCZYNSKI.

151, 152. Metric Differential Geometry.—The application of the calculus to the metric theory of twisted curves and surfaces in space. Prerequisite: course 31. Two consecutive majors. Autumn and Winter Quarters, ASSOCIATE PROFESSOR WILCZYNSKI. [Not given in 1911–12.]

154. Projective Differential Geometry.—This course gives a brief account of Lie's theory, with applications to the theory of invariants of systems of linear differential equations. The projective differential properties of plane and space curves, of surfaces and congruences, then present themselves as a result of interpreting this invariant theory geometrically. Text: Wilczynski's *Projective Differential Geometry of Curves and Ruled Surfaces*. B. G. Teubner, Leipzig, 1906. Prerequisite: An elementary knowledge of differential equations and projective geometry. Mj. ASSOCIATE PROFESSOR WILCZYNSKI. [Not given in 1911–12.]

156. Theory of Plane Curves.—Projective and metric, differential and integral properties. Texts: Salmon's *Higher Plane Curves* and Wilczynski's *Projective Differential Geometry of Curves and Ruled Surfaces.* Prerequisite: An elementary knowledge of differential equations and projective geometry. Mj. ASSOCIATE PROFESSOR WILCZYNSKI. [Not given in 1911–12.]

157. Theory of Ruled Surfaces and Space Curves.—Primarily from the point of view of projective differential geometry. Text: Wilczynski's *Projective Differential Geometry of Curves and Ruled Surfaces.* Prerequisite: Course 156. Mj. ASSOCIATE PROFESSOR WILCZYNSKI. [Not given in 1911–12.]

158. Theory of Surfaces and Congruences, with special emphasis upon the projective differential properties. Prerequisite: Mathematics 157. Mj. ASSOCIATE PROFESSOR WILCZYNSKI. [Not given in 1911–12.]

160. Analytic Mechanics, I.—Introductory course. Prerequisite: Differential Equations. Mj. Summer Quarter, ASSISTANT PROFESSOR LUNN.

161. Advanced Analytic Mechanics, I, II.—(Astronomy 20, 21B.) Two consecutive majors. Autumn and Winter Quarters, ASSOCIATE PROFESSOR LAVES.

162. Vector Analysis.—The elements of vector algebra, vector differentiation and integration, and the linear vector function; illustrated by typical applications to geometry, mechanics, and physics. Prerequisite: courses 31, and 49. Mj. Summer and Spring Quarters, ASSISTANT PROFESSOR LUNN.

163. Theory of Attraction and the Potential.—The potential function of gravitation and electrostatics; Laplace's equation, Green's functions, and harmonic analysis; extensions to cases of heterogeneous media, with sketch of the abstract theory as related to linear differential equations of the second order. Prerequisite: courses 49 and 160. ASSISTANT PROFESSOR LUNN. [Not given in 1911–12.]

166. Hydrodynamics.—Kinematics of continuous media and dynamical theory of typical forms of motion in perfect and viscous fluids, with special emphasis on analytic methods of general use in mathematical physics. Mj. ASSISTANT PROFESSOR LUNN. [Not given in 1911–12.]

167. Theory of Elasticity.—The geometry of strain in a continuous medium, dynamical relations of stress and strain; detailed study of selected problems in the equilibrium and motion of elastic solids. Prerequisite: Advanced Calculus and Analytic Mechanics. Mj. Spring Quarter, ASSISTANT PROFESSOR LUNN.

170. Average and Probability.—The theory of average and probability for finite and infinite sets of elements; the statistical treatment of observations and the method of least squares; introduction to statistical mechanics, with examples from the theories of molecules and electrons. Prerequisite: Differential Equations. Mj. Autumn Quarter, ASSISTANT PROFESSOR LUNN.

172. Partial Differential Equations of Mathematical Physics; the Conduction of Heat.—A study of certain typical linear partial differential equations occurring in the analytic representation of physical theories, and of the functional expansions of solutions satisfying given boundary conditions; with special reference to the concrete phenomena and physical analogies from which the abstract theory has been generalized. Prerequisite: courses 49 and 160. Mj. ASSISTANT PROFESSOR LUNN. [Not given in 1911–12.]

181, 182. General Seminar.—For the consideration of reports of current research and of literature, especially of a fundamental or critical nature. Two consecutive majors. Winter and Spring Quarters, PROFESSOR MOORE.

ASTRONOMY AND ASTROPHYSICS

OFFICERS OF INSTRUCTION

EDWIN BRANT FROST, A.M., Professor of Astrophysics, and Director of the Yerkes Observatory.

SHERBURNE WESLEY BURNHAM, A.M., Professor of Practical Astronomy, and Astronomer in the Yerkes Observatory.

EDWARD EMERSON BARNARD, A.M., Sc.D., Professor of Practical Astronomy and Astronomer in the Yerkes Observatory.

GEORGE ELLERY HALE, S.B., Sc.D., LL.D., Non-resident Professor of Astrophysics (Mt. Wilson, Cal.).

KURT LAVES, A.M., PH.D., Associate Professor of Astronomy.

FOREST RAY MOULTON, A.B., PH.D., Associate Professor of Astronomy.

JOHN ADELBERT PARKHURST, S.M., Instructor in Practical Astronomy at the Yerkes Observatory.

STORRS BARROWS BARRETT, A.B., Secretary and Librarian of the Yerkes Observatory.

FREDERICK SLOCUM, A.M., PH.D., Instructor in Astrophysics at the Yerkes Observatory.

WILLIAM DUNCAN MACMILLAN, PH.D., Instructor in Astronomy.

FELLOWS, 1911–12

CURWIN HENRY GINGRICH, A.M. OLIVER JUSTIN LEE, A.B.

INSTRUCTIONAL WORK

The work of the Department of Astronomy and Astrophysics is divided into two parts: (1) Work at the University, comprising: (*a*) elementary instruction in general Astronomy, both theoretical and practical; (*b*) preliminary training in the principles and methods of work underlying the science of Astrophysics (given in part in the Department of Physics); (*c*) graduate and research work in Celestial Mechanics. (2) Graduate and research work in Practical Astronomy and Astrophysics in the Yerkes Observatory at Lake Geneva.

In the work at the University, given by Associate Professors Laves and Moulton and Dr. MacMillan, emphasis will be laid on the development of the mathematical principles and methods which form the basis of the physical sciences. In addition to the courses in Descriptive Astronomy, Introduction to Celestial Mechanics, and Analytical Mechanics, courses in the various branches of Celestial Mechanics will be given within periods not exceeding three years. The most

fundamental subjects will be arranged so as to recur at regular intervals, while other more special topics will vary from time to time. The general object of the instruction will be (1) to give experience and preliminary training in the work of observation and reduction; (2) to furnish the student an adequate mathematical basis for successful work in Celestial Mechanics; (3) to direct research work in Celestial Mechanics.

FACILITIES

For instruction in Practical Astronomy a students' observatory is maintained. It is equipped with a modern Warner & Swasey equatorial telescope of 6½ inches' aperture which is provided with a filar micrometer, a 5-inch refractor, a 3-inch Bamberg transit instrument, a Bamberg universal instrument, a Riefler sidereal clock, a chronometer, and various smaller accessories. The laboratory courses offered by the Department of Physics afford excellent preliminary training for the work in Astrophysics.

In the work at the Yerkes Observatory, the advanced student is made familiar with modern methods of research in various branches of Practical Astronomy and Astrophysics. The rapid development of the latter science within the last two decades has been fully recognized in the equipment of the Observatory; the special laboratory facilities make many investigations possible which cannot be carried on where the equipment is less complete. In general, the work in progress during the year 1911–12 will include: Researches in solar physics with the spectroscope, spectroheliograph, and photoheliograph; micrometric observations of double stars, planets, satellites, nebulae, and comets; photographic studies of stellar spectra and determinations of motions in the line of sight; photography of stars, comets, nebulae, etc.; photographic investigations of stellar parallax; research in visual and photographic photometry; special astrophysical researches. The opportunity of taking part in these investigations is deemed of more advantage to the qualified student than set courses of instruction; but regular programmes of work, with courses of collateral reading, will be laid out as conditions may require.

Admission to Yerkes Observatory

The Yerkes Observatory is open only to graduate students who have completed the necessary preliminary studies and have had the requisite experience in practical laboratory and observatory work. Students wishing to work at the Observatory should first consult the Director of the Yerkes Observatory, Williams Bay, Wis., and obtain his approval.

DEGREES

The Master's degree.—Students working for a Master's degree in Astronomy are advised to choose three majors of graduate work either in the Department of Mathematics or Physics and six majors in the Department of Astronomy, from courses numbered 5, 6, 7, 22, and 23.

The degree of Doctor of Philosophy.—The courses prescribed for the Master's

degree together with three other graduate courses will meet the requirement for the Doctor's degree, where Astronomy is the minor subject.

Candidates for the Doctor's degree, with Astronomy as major subject, are expected to make their secondary subject either Mathematics or Physics. Students intending to specialize in the lines of Astrophysics will be required to take the work in Theoretical Physics, Advanced Experimental Physics, Sound and Light, and Physical Manipulation. The courses in Astronomy which will be required depend on the phase of the subject which the candidate elects for his special work, and will be arranged for each candidate during the progress of his work. Students specializing in Celestial Mechanics are expected to spend six months at the Yerkes Observatory, and those working there in Practical Astronomy and Astrophysics are expected to spend six months at the University.

CLUB

The Departmental Club meets fortnightly for the review of memoirs and books, and for the presentation of results of research. The club is conducted by the members of the faculties of Mathematics and Mathematical Astronomy. Graduate students of Mathematical Astronomy are expected to attend regularly and, so far as possible, to participate actively in the meetings of the club.

SEQUENCE OF EARLY COURSES

Undergraduate students who desire to specialize in Astronomy are recommended to take course 36 and its antecedents in Mathematics, and courses 3, 5, 6, 22, and 23 in Astronomy, as a basis for further work.

COURSES OF INSTRUCTION

At the University

Junior College Courses

1. Descriptive Astronomy (Shorter Course).—An elementary course, dealing with fundamental facts, principles, and methods. Frequent access to the observatory. Mj. Spring Quarter, Associate Professors Moulton and Laves.

3. Descriptive Astronomy.—Prerequisite: Plane Trigonometry. Mj. Winter and Spring Quarters, Dr. MacMillan.

Senior College Courses

5. Analytic Mechanics, I.—An introductory course. Prerequisite: Mathematics 27. Mj. Autumn Quarter, Associate Professor Laves.

6. Analytic Mechanics, II.—Prerequisite: Astronomy 5. Mj. Winter Quarter, Associate Professor Laves.

7. Spherical and Practical Astronomy.—Prerequisite: Mathematics 27 and Astronomy 3. 1½ Mj. Spring Quarter, Associate Professor Laves.

Graduate Courses

20. Advanced Analytic Mechanics, I.—General integrating principles of the motion of systems. Generalized co-ordinates, Hamilton's and Jacobi's investigations. Prerequisite: courses 5 and 6. Mj. Autumn Quarter, Associate Professor Laves.

21B. Advanced Analytic Mechanics, III.—Dynamics of rigid bodies. (*a*) Systems of vectors. Distribution of mass. Instantaneous motion. (*b*) Dynamics of rotary bodies. Prerequisite: course 20. Mj. Winter Quarter, Associate Professor Laves.

22. Introduction to Celestial Mechanics, I.—Helmholtz's theory of the heat of the sun. Central forces; demonstration of law of gravitation; problem of two bodies; the ten integrals of planetary motion; considerations on perturbations. Prerequisite: course 5. Mj. Winter Quarter, Dr. MacMillan.

23. Introduction to Celestial Mechanics, II.—Properties of conic section motion, special cases of the problem of three bodies; method of variation of parameters; considerations on absolute perturbations; determination of two geocentric distances from the observations; determination of elements and methods of improving them; variations of elements. Prerequisite: course 22. Mj. Spring Quarter, Dr. MacMillan.

50. Modern Theories of Analytic Differential Equations with Applications to Celestial Mechanics.—Properties of solutions of general system of *n*th order as functions of independent variable, of parameters, of initial values of dependent variables. Solutions developed as power series in independent variable, in parameters and initial values of dependent variables, by the Cauchy-Lipschitz process, by the Picard approximation process, by continued variation of perameters. Applications to elliptic and hyperelliptic functions, to celestial mechanics and periodic solutions of problem of three bodies. Linear equations with application to hypergeometric functions. Linear equations with periodic coefficients. (See XVII, 127.) 2 Mj. Winter and Spring Quarters, Associate Professor Moulton.

31, 32, 33. Research Courses at the Observatory.—Prerequisites: See Admission to Yerkes Observatory, p. 17. DMj. Each Quarter, Professors and Instructors resident at Yerkes Observatory.

35. Absolute Perturbations.—Prerequisite: courses 22, 23. Mj. Autumn Quarter, Associate Professor Moulton.

PHYSICS

OFFICERS OF INSTRUCTION

Albert Abraham Michelson, Ph.D., Sc.D., LL.D., F.R.S., Professor and Head of the Department of Physics.
Robert Andrews Millikan, Ph.D., Professor of Physics.
Charles Riborg Mann, Ph.D., Associate Professor of Physics.
Carl Kinsley, A.M., M.E., Associate Professor of Physics.
Henry Gordon Gale, Ph.D., Assistant Professor of Physics.
J. Harry Clo, Ph.D., Assistant in Physics.
John Yiubong Lee, S.B., Assistant in Physics.
Harvey Brace Lemon, Ph.D., Assistant in Physics.

FELLOWS, 1911–12

Jesse Le Mar Brenneman, S.B.
Carl Robert Englund, S.B.
John Eustace Davis, A.B.
Leopold Joseph Lassalle, S.B.
Jens Madsen Rysgaard, A.B.

INSTRUCTIONAL WORK

The instructional work in Physics is directed toward the following ends: (1) The training of original investigators in physics; (2) the training of men competent to fill college and university positions as teachers of physics; (3) the training of teachers of physics for secondary schools; (4) the training of pre-engineering and pre-medical students for later professional work; (5) the training of the general student in scientific methods of work, and in the understanding of the place of physical science in the modern world. From the most elementary to the most advanced courses, the laboratory and the problem method of instruction are emphasized.

FACILITIES

The Ryerson Physical Laboratory has been enlarged and remodeled with especial reference to offering the best facilities for research work. The entire lower floor and basement are given up to private research rooms. A well-equipped shop, with skilled instrument makers, furnishes opportunity for the construction of special pieces of research apparatus. The equipment has been selected with reference to the needs of research, and includes spectroscopic instruments of highest power, electrical apparatus for work with alternating and direct currents through all ranges of potential, and appliances for high

and for low temperature work, including a liquid air plant. The library of the department is well equipped for research purposes. A physics club is conducted by the members of the Department, and meets regularly for the discussion of the results of research work done in the Ryerson Laboratory and elsewhere.

DEGREES

All candidates for the S.B. degree who elect their major work in Physics are required to take courses 3, 4, and 5, and either six majors selected from courses 11, 12, 13, 15, 16, 17, 18, and 25, or three of these and three Senior College courses in one of the following departments: Mathematics, Astronomy, Chemistry, Geology, or Geography. Pre-engineering students are required to take courses 3, 4, and 5; pre-medical students are required to take courses 3 and 4.

The Master's degree.—Candidates for the Master's degree in Physics are required to take 8 majors in physics and related subjects, and to present in addition a thesis embodying the results of a laboratory problem. All courses in the Department numbered 11 or above, except course 20, will be counted in satisfaction of this requirement.

The degree of Doctor of Philosophy.—Candidates for the Doctor's degree with Physics as a minor subject must take courses 3, 4, and 5, and six of the following: 11, 12, 13, 15, 16, 17, 18, 25, 31–36, 51, 52, 56, 57, 58, and 59. When physics is one of two minor subjects, the courses must be arranged by consultation with the Department.

All candidates for the Doctor's degree with Physics as the major subject must take the following courses: 3, 4, 5, 11, 12, 13, 15, and 25, or their equivalent; 3 majors selected from courses 16, 17, 18, 37, 38, and 39; courses 31–36, and three additional graduate courses selected by the student. Each candidate must also present a thesis embodying the results of original research in some subject approved by the Department. The time required for the thesis work generally varies from three to six quarters.

PREPARATION FOR TEACHING

Students preparing to teach physics in secondary schools are expected to have completed courses 3, 4, 5, 14, and 25, and not less than three of courses 11, 12, 13, 15, 16, 17, and 18. See also courses in Physics in the School of Education.

LABORATORY FEES

There is a laboratory fee of $5 for all major courses involving laboratory work in the Department of Physics.

COURSES OF INSTRUCTION

Junior College Courses

1. Elementary Physics.—A first course in the elements of Physics designed primarily for students who do not present entrance Physics. Mj. Autumn Quarter. Dr. Clo.

2. **Elementary Physics.**—A continuation of the preceding course, covering the subjects of electricity, sound, and light. Prerequisite: course 1. Mj. Winter Quarter, Dr. Clo.

3. **Mechanics, Molecular Physics, and Heat.**—A general college course in mechanics, molecular physics, and heat, presented mainly from the experimental point of view. Prerequisite: entrance Physics, or course 2. Mj. Summer Quarter, 2 sections, Assistant Professor Gale and Dr. Clo; Autumn Quarter, 3 sections, Associate Professors Mann and Kinsley and Assistant Professor Gale; Winter Quarter, Assistant Professor Gale; Spring Quarter, Associate Professor Kinsley.

4. **Electricity, Sound, and Light.**—A general college course in electricity, sound, and light, presented mainly from the experimental point of view, and involving the performance of eighteen laboratory exercises in electricity, four in sound, and six in light. Prerequisite: Physics 3. Mj. Summer Quarter, 2 sections, Dr. Lemon and Dr. Clo; Winter Quarter, 3 sections, Associate Professors Mann and Kinsley and Dr. Wright; Spring Quarter, Dr. Lemon.

5. **Lecture Demonstration Course.**—A course of lectures, demonstrations, and recitations supplementing courses 3 and 4 and completing a year's work in college Physics. Recent discoveries and developments in Physics are given especial attention. 5 hours a week. Prerequisite: Physics 4. Mj. Summer and Spring Quarters, Dr. Clo and Dr. Lemon.

6. **General Survey of Physical Science.**—A lecture demonstration course in which familiar physical phenomena are presented and discussed with reference both to their scientific interpretation and to their relations to modern life. Primarily for Arts students. Not accepted in satisfaction of specific requirements in Physics. Mj. Spring Quarter, Associate Professor Mann.

Senior College Courses

10. **Elementary Mathematical Physics.**—A lecture course on the application of Elementary Calculus to Physics and Chemistry, and practice in the solution of problems. Prerequisite: Physics 3 and 4 and not less than one major of Calculus. Autumn Quarter, Assistant Professor Gale.

11. **Heat and Molecular Physics.**—A lecture course for advanced and graduate students, covering the Kinetic Theory, Capillarity, Elementary Thermodynamics, Solution, and Electrolysis. Prerequisite: Physics 4 and Calculus. Mj. Professor Millikan. [Not given in 1911–12.]

12. **Light.**—A lecture course for advanced students covering the more important sections of geometrical and physical optics. Prerequisite: Physics 4 and Calculus. Mj. Assistant Professor Gale. [Not given in 1911–12.]

13. **Electricity and Magnetism.**—A course of advanced work in theoretical Electricity and Magnetism, intended to supplement the work in General Physics or to prepare for graduate work. Prerequisite; Physics 4 and Calculus. Mj. Spring Quarter, Associate Professor Kinsley.

14. **The Pedagogy of Physics.**—A course designed for teachers of Physics in high schools, consisting of lectures and discussions upon choice of subject-matter and methods of presentation best suited to elementary courses in Physics. Prerequisite: courses 3, 4, and 5, or equivalents. Mj. DMj. Summer Quarter, Professor Millikan and Dr. Bishop.

15. **Mechanics and Wave Motion.**—A lecture course on the physical meaning and the mathematical derivation of the fundamental equations of Mechanics and Wave Motion. Prerequisite: Physics 4 and Calculus. Mj. Spring Quarter Assistant Professor Gale.

16. **Experimental Physics (Advanced): Molecular Physics and Heat.**—A course of advanced laboratory work involving the determination of vapor pressures and densities, coefficients of friction of gases and liquids, molecular electrical conductivities, freezing- and boiling-points, latent and specific heats, high and low tem-

peratures, radio-active constants, etc. Prerequisite: course 4. Mj. Spring Quarter, PROFESSOR MILLIKAN AND DR. LEMON.

17. Experimental Physics (Advanced): Light.—A course of advanced laboratory work in Light, consisting of accurate measurements in diffraction, dispersion, interference, and polarization. Prerequisite: course 4. Mj. Summer Quarter, ASSISTANT PROFESSOR GALE; Winter Quarter, ASSOCIATE PROFESSOR MANN.

18. Experimental Physics (Advanced): Electricity and Magnetism.—Laboratory work of the same grade as courses 16 and 17, but consisting of measurements in Electricity and Magnetism. Prerequisite: Physics 4. Mj. Summer and Autumn Quarters, ASSOCIATE PROFESSOR KINGSLEY.

20. Physical Manipulation.—A series of exercises not provided in the regular courses of Experimental Physics, but important to the teacher or advanced student. It consists of the following groups:

Group A. *Shop Work* includes the cutting, filing, drilling, tapping, soldering, and polishing of metal, screw cutting, and elementary lathe work.

Group B. *Glass Work* includes the cutting, grinding, drilling, polishing, and testing of glass.

Group C. *Glass Blowing* includes the simpler processes in glass blowing, such as cutting, bending, and joining of tubes, blowing bulbs, sealing in electrodes, etc.

Group D. *Chemical Processes and Physical Preparations* include the silvering of glass, cleaning and distillation of mercury, preparation of fibers for suspension, and materials useful in experimental work.

Laboratory fee, $5. Mj. Summer Quarter, DR. LEMON.

21. Analytic Mechanics.—An introductory course (Astronomy 5). Autumn Quarter, ASSOCIATE PROFESSOR MOULTON.

25. History of Physical Science.—A continuation of course 9 in Philosophy, History of Science (ancient). A discussion of the origin and evolution of modern physical science in its relation to the growth of civilization. Prerequisite: 18 majors credit in college. Mj. Autumn Quarter, ASSOCIATE PROFESSOR MANN.

26. Teaching of Physical Science.—A review of the history of science teaching in America and abroad, and a discussion of present problems and their solution in special cases. Mj. Spring Quarter, ASSOCIATE PROFESSOR MANN.

GRADUATE COURSES

31, 32, 33. Theoretical Physics.—A series of lectures chiefly in Theoretical Physics, Hydrodynamics, Elasticity, Capillarity, Molecular Physics, Thermodynamics, Wave-Motion, Sound, Optical Theories, Electricity and Magnetism. 4 hours a week. Prerequisite: Physics 11, 13, and 15, and Calculus. Autumn, Winter, and Spring Quarters, PROFESSOR MICHELSON.

34, 35, 36. Theoretical Physics.—A series of lecture courses. Alternating with 31, 32, and 33. Prerequisite: same as for 31. 3Mj. Autumn, Winter, and Spring Quarters, PROFESSOR MICHELSON.

37, 38, 39. Experimental Physics.—A course of laboratory work, chiefly devoted to the repetition of classical experiments, such as, Determination of the Mechanical Equivalent of Heat; Maxwell's "V"; Hertzian Oscillation; Relative and Absolute Wave-Lengths, etc. 10 hours a week. Prerequisite: Physics 16, 17, and 18. 3Mj. Autumn, Winter, and Spring Quarters, PROFESSORS MICHELSON AND MILLIKAN.

40, 41, 42, 43. Research Course.—This course is intended for graduate students who are prepared to undertake special research. Except in the case of a purely mathematical problem, the entire time is to be devoted to work in the laboratory. DMj. Summer, Autumn, Winter, and Spring Quarters, PROFESSORS MICHELSON AND MILLIKAN.

48. Spectrometry, I.—Laboratory work in photographing and measuring the spectra of various elements. Use of the concave grating, echelon, and interferometer. Prerequisite: two years of college Physics and Calculus. Mj. Spring Quarter, ASSISTANT PROFESSOR GALE.

49. Spectrometry, II.—A continuation of course 48. Assistant Professor Gale. [Not given in 1911–12.]

51. Thermodynamics.—Lectures upon the fundamental principles underlying the mechanical theory of heat and the application of these principles to physical and thermochemical problems. Prerequisite: two years of college Physics and Calculus. 5 hours a week. Mj. Autumn Quarter, Professor Millikan.

52. Electron Theory, I.—A course of graduate lectures, covering the work of the last ten years on the electrical properties of gases, the electron theory, and radioactivity. Prerequisite: same as for 51. 5 hours a week. Mj. Spring Quarter, Professor Millikan.

53. Electron Theory, II.—A continuation of 52, dealing with the application of the electron theory to metallic conduction, to the Seebeck, Peltier, Thomson, and Hall effects, to optical phenomena in magnetic fields, to the subject of electromagnetic mass, etc. 5 hours a week. Mj. Summer Quarter, Professor Millikan.

54. Heat Radiation.—A combined lecture and seminar course dealing primarily with the Thermodynamics of Radiation. The ground covered is essentially the same as that contained in Planck's *Wärme Strahlung*. Prerequisite: Elementary Thermodynamics. Mj. Professor Millikan. [Not given in 1911–12.]

56. Electron Theory of Electricity.—Electrical phenomena and their place in the electron theory. The discoveries of Roentgen, Zeeman, Thomson, and Rutherford and the modern theory of electricity. Prerequisite: same as for 51. M. Summer Quarter, First Term, Associate Professor Kinsley.

57. The Theory of Alternating Currents.—A discussion of stationary and moving circuits, including transformers, transmission circuits, and the various types of dynamos and motors. Demonstrations will be given. Prerequisite: same as for 51. Mj. Associate Professor Kinsley. [Not given in 1911–12.]

58. Transient Electrical Phenomena.—Theory and demonstration of current flow before the steady state is reached. Oscillations in power circuits and problems in telephone and telegraph transmission. Prerequisite: course 18 and Calculus. Mj. Winter Quarter, Associate Professor Kinsley.

59. Modern Spectroscopy.—A lecture course on the theory and use of spectroscopic apparatus and a discussion of spectroscopic and astrophysical phenomena. Prerequisite: same as for 51. Assistant Professor Gale.

60. Light Waves and Their Uses.—A course of graduate lectures on recent developments in physical optics. Prerequisite: two years of college Physics and Calculus. 3 hours a week. Professor Michelson. [Not given in 1911–12.]

61. Physical Optics.—Lectures on the fundamental equations of Theoretical Optics and on recent experimental results. Mj. Summer Quarter, 7:00, Assistant Professor Gale.

70. Physics Club.—This organization, consisting of all instructors, graduate and advanced students in the Department, meets on Monday of each week from 4:30 to 6:00 for the discussion of recent research.

CHEMISTRY

OFFICERS OF INSTRUCTION

JOHN ULRIC NEF, PH.D., Professor and Head of the Department of Chemistry.
JULIUS STIEGLITZ, PH.D., SC.D., Professor of Chemistry and Director of Analytical Chemistry.
HERBERT NEWBY MCCOY, PH.D., Professor of Chemistry.
ALAN W. C. MENZIES, PH.D., Assistant Professor of Chemistry.
HERMAN IRVING SCHLESINGER, PH.D., Assistant Professor of Chemistry.
THOMAS BRUCE FREAS, A.B., Curator and Instructor in Chemistry.
EDITH ETHEL BARNARD, PH.D., Instructor in Chemistry.
ERNEST ANDERSON, PH.D., Research Instructor in Chemistry.
———— ————, PH.D., Instructor in Chemistry.
ETHEL MARY TERRY, S.B., Associate in Chemistry.
CHARLES HERMAN VIOL, S.B., Assistant in Chemistry.
PARKE HATFIELD WATKINS, S.B., Assistant in Quantitative Analysis.
GUY ARTHUR REDDICK, A.B., Research Assistant.
JACOB MARTIN JOHLIN, PH.D., Research Assistant.

WILLIAM CABLER MOORE, PH.D., Instructor in Chemistry, Columbia University (Summer Quarter, 1911).

FELLOWS, 1911–12

GEORGE OLIVER CURME, JR., S.B.
JOHN WILLIAM EDWARD GLATTFIELD, S.B., S.M., Loewenthal Fellow.
OSCAR FRED HEDENBURG, A.B.
WILLIAM BUELL MELDRUM, S.M.
PAUL DAVID POTTER, A.B.
CLARE CHRISMAN TODD, S.B., Swift Fellow.

INSTRUCTIONAL WORK

The Department aims to prepare students (1) to teach in colleges or universities; (2) to teach in secondary schools; (3) to fill positions as technical experts or assistants in chemical industries; (4) to become analysts in commercial and sanitary laboratories. The elementary courses may be taken with advantage by students having none of these ends in view.

Special stress will be placed on thoroughness of preparation and the symmetrical development of the student's knowledge. The object of the courses will be not so much to train specialists as to prepare the student to undertake

intelligently all kinds of work of a chemical nature. Those intending to become practical chemists will find a thorough course of purely scientific chemistry the best basis for future specialization in any branch of the subject. Those who incline toward inorganic chemistry will be required to do much physical and a considerable amount of organic work; those proposing to become organic chemists will be required to do work in inorganic chemistry of a more advanced nature than that given in the elementary and analytical courses, and some physical chemistry, etc.

RESEARCH

Students are encouraged to begin research work as soon as their preparation justifies it. Facilities for research in all lines, whether of inorganic, organic, or physical chemistry, are provided. Special opportunities to pursue entirely independent research work will be given to maturer students who have already obtained the Doctor's degree.

DEGREES

The degree of Ph.D.: Chemistry as major subject.—The requirements for the degree of Doctor of Philosophy are:

1. The presentation of a thesis embodying the result of original research in General Inorganic, Organic, Physico-organic, or Physical Chemistry. This must constitute a real contribution to knowledge, and the work is usually done under the direction of an officer of the department.

2. Especially thorough and mature knowledge of the branches of Chemistry touched by the thesis, and a sufficient knowledge of other fundamental phases of the science.

The general requirements for all candidates, in advance of general chemistry, are as follows: courses 4*, 6–9, 60–62, and two majors selected from courses 10, 11, 13–19, 30–32.

In addition to the above, the requirements, arranged according to the thesis subject, are as follows:

General Chemistry: courses 50–52, 35, and 63, and one major taken from courses 13–19, 30–37, 64; *Organic Chemistry:* courses 32, 35–37, 50, and one major from 10, 13–19, 51, 52, 63, 64; *Physico-organic Chemistry:* courses 31, 35, 36, 50, and 63, and one major taken from courses 10, 13–19, 51, 52, 64, and 65. *Physical Chemistry:* courses 50, 51, 35, 63, 64, and one major taken from courses 10, 13–19, 30–32, 35–37, 52. In addition to one set of these specific requirements at least six half-majors will be chosen from the special lecture courses, 40–44, 65–71, 80, 81, 83. The research work will require from four to six quarters.

3. Sufficient work in one or two minor subjects—for instance, if Physics is a minor subject, two years of College Physics, courses 1, 2, 3, and three of the courses 11, 12, 13, 16, 17, 18. In addition to the regular minor subject, all candidates are advised to take mineralogy and crystallography.

* Course 4 may be omitted when advanced work in Organic Chemistry is taken.

The degree of Doctor of Philosophy: Chemistry the secondary subject.—When Chemistry is a secondary subject, the requirement is determined after conference with the Head of the Department in which the major work is done. Courses 2, 3, 6, 7, and 8, and four other majors in advance of 8, will be required when Chemistry is the only secondary subject; courses 2, 3, 6, 7, and 8, and one other major, when Chemistry is one of two secondary subjects. Elementary Physical Chemistry (60 and 61) or Organic Chemistry, according as the major subject belongs to the Physical or the Biological Group, is recommended.

The Master's degree.—For the Master's degree a dissertation and eight majors of graduate work in Chemistry are required if all the work is in this Department. These majors must be selected from courses in advance of 9, with the approval of the Head of the Department. Courses prerequisite to these must be taken, but cannot be counted in reckoning the eight required majors.

SPECIAL COURSES NOT LEADING TO A HIGHER DEGREE

Special students.—Special or unclassified students, not candidates for a degree, will be received, but in every case they will be required to give evidence, satisfactory to the instructors, that their previous training has been sufficient to enable them to derive full profit from the courses they propose to take.

Preparation for teaching.—While students who have not taken the work required for the Doctor's or Master's degree are not usually recommended for college or university positions, the Bachelor's degree, with a sufficient amount of work in Chemistry, is at present considered preparation for teaching in secondary schools. In general the work in Chemistry should include at least courses 1, 2, 3, 4, 6, 7, 8, 60, 61, and 80, or their equivalent, as well as work in the College of Education. The prospective teacher in secondary schools should be prepared to teach at least one science besides Chemistry.

Preparation for technical positions.—1. Thorough scientific training in all branches of Chemistry required for the Doctor's degree forms the best basis for a career as a chemical expert in any branch of chemical industry. With this preparation, the principles and details of technical processes are quickly grasped, advances in industrial processes are intelligently followed, and newly discovered principles are readily applied.

2. Students who have taken from ten to fifteen majors of work in the Department are able to fill satisfactorily positions as assistants in technical and analytical laboratories and, after some practical experience, to advance to positions of independent responsibility. Students should take courses 1 to 10, inclusive, one or two majors in courses 13–19, and courses 60 and 62. If the student's work is primarily in Organic Chemistry, he should take, if possible, two or three courses selected from Nos. 30–32 and 35–37; if his work is in Inorganic Chemistry primarily, he should take courses 50–52. Students taking the fuller preparation outlined are given the preference in answering requests received by the Depart-

ment; but students with less complete training are also sought by technical firms.

3. The Department gives, with other departments (notably Physics and Mathematics) of the University, and the Department of Manual Training of the University High School, the equivalent of three years of a four-years' course in Chemical Engineering. Students are able to take a large part of this work in the purely scientific fundamental branches, while they are candidates for a Bachelor's degree.

The Department does not pledge itself to secure positions for those who have studied in it; but, as a matter of fact, competent students find suitable places quickly, and in the past the demand for chemists has far exceeded the supply.

LABORATORY FEES

There is a laboratory fee of $5 per major for all courses involving laboratory work in the Department of Chemistry.

COURSES OF INSTRUCTION

NOTE.—After course 0, the courses are arranged in groups according to subjects: courses 10–29 include courses in Analytical Chemistry, 30–49 in Organic Chemistry, 50–59 in Inorganic Chemistry, 60–71 in Physical Chemistry; 80–89 are general in nature, and 90–93 are research courses. Nos. 12–19, 30–34, 40–43, 60–62, and 68–71 are open to, and suitable for, Senior College students.

PRIMARILY FOR THE JUNIOR COLLEGES

1. Elementary General Chemistry: Inorganic, I.—Prerequisite: preparatory Physics. DM. Summer Quarter, First Term. Classroom, 6 hours a week; laboratory, 12 hours a week; MISS TERRY. Mj. Autumn Quarter. Classroom, 3 hours a week; laboratory, 6 hours a week; ASSISTANT PROFESSOR MENZIES.

2. General Chemistry: Inorganic, II.—(Continuation of course 1.) Prerequisite: course 1. DM. Summer Quarter, Second Term, MISS TERRY. Mj. Winter Quarter, ASSISTANT PROFESSOR MENZIES.

3. General Chemistry: Inorganic, III.—(Continuation of course 2.) Prerequisite: course 2. Mj. Spring Quarter, DR. ———.

NOTE.—Courses 1, 2, and 3 are consecutive courses. Separate credit is given for each, but students are not advised to take one course only. The aim of these courses is to give a definite idea of the fundamental principles of Chemistry, and not to overburden the student with a mass of unconnected facts. The conception of chemical equilibrium and the modern theory of solutions are freely used. The lectures will be experimental to a considerable extent. The courses are designed to meet the wants not only of those who wish to go deeper into chemistry, but of all who wish to study the science as part of a liberal education. The lectures and classroom work of 1, 2, and 3 may be taken by graduate students without the laboratory work or laboratory fee.

2S. General Chemistry: Inorganic.—(First Course.) For students who have had Preparatory Chemistry. Prerequisite: preparatory Chemistry and preparatory Physics, one unit each. DM. Summer Quarter, First Term. Classroom, 6 hours a week; laboratory, 12 hours a week; ASSISTANT PROFESSOR MENZIES. Mj. Autumn Quarter. Classroom, 3 hours a week; laboratory, 6 hours a week; PROFESSOR MCCOY.

3S. General Chemistry: Inorganic.—(Continuation of course 2S.) DM. Summer Quarter, Second Term, DR. MOORE. Mj. Winter Quarter, DR.———.

NOTE.—Course 2, Winter Quarter, is a continuation of course 1, but may be entered by those having credit for admission chemistry. Whenever, in exceptional cases, the preparation of a student in 2S justifies it, qualitative analysis may be substituted for 3S.

4. Elementary Organic Chemistry.—Prerequisite: course 3 or 3S. Mj. Autumn Quarter. Classroom, 3 hours a week; laboratory, 6 hours a week; PROFESSOR STIEGLITZ.

PRIMARILY FOR THE SENIOR COLLEGES

6. Qualitative Analysis.—(Introductory Course.) The lectures deal with the chemistry of the analytical reactions, and special attention is given to the development

and application of the laws of equilibrium and solutions. This course is, in an important sense, one in advanced General Chemistry. Classroom, 2 hours a week; laboratory, 8 or 16 hours a week. Prerequisite: course 3 or 3S. Mj. or DM. Summer and Autumn Quarters, ASSISTANT PROFESSOR SCHLESINGER; Winter Quarter, MISS TERRY; Spring Quarter, PROFESSOR STIEGLITZ AND MISS TERRY.

NOTE.—Courses 6, 7, and 10 form a continuous course, which may be begun in any quarter. The aim of courses 6, 7, and 10 will be to train the student to do intelligent analytical work, based on a knowledge of the scientific principles of the subject, and to apply and amplify his knowledge of General and Physical Chemistry.

7. Qualitative Analysis.—(Continuation of course 6.) Mj. or DM. Summer and Autumn Quarters, ASSISTANT PROFESSOR SCHLESINGER; Winter and Spring Quarters, MISS TERRY.

8. Quantitative Analysis.—(Introductory Course.) Chiefly laboratory work in gravimetric and volumetric analysis. Laboratory, 8 or 16 hours a week; lecture, 1 hour. Prerequisite: course 7. Medical students will be admitted to the course after having taken course 6. Mj. or DM. Summer, Autumn, and Spring Quarters, DR. BARNARD; Winter Quarter, PROFESSOR STIEGLITZ.

NOTE.—Courses 8, 9, and 11 form a continuous course which may be begun in any quarter.

9. Quantitative Analysis.—(Continuation of course 8.) Mj. or DM. Laboratory, 10 or 20 hours a week. Mj. Summer, Autumn, and Spring Quarters, DR. BARNARD; Winter Quarter, PROFESSOR STIEGLITZ.

PRIMARILY FOR THE GRADUATE SCHOOL

10. Advanced Qualitative Analysis.—Prerequisite: course 7. Mj. or DM. Laboratory, 10 or 20 hours a week. Open to Senior College students. Continuation of courses 6 and 7. Summer, Autumn, and Winter Quarters, ASSISTANT PROFESSOR SCHLESINGER; Spring Quarter, MISS TERRY.

11. Advanced Quantitative Analysis.—(Continuation of courses 8 and 9.) Open to students in the Senior Colleges. Mj. or DM. 10 or 20 hours a week. Winter Quarter, PROFESSOR STIEGLITZ.

12. Elementary Spectrum Analysis (Qualitative).—Emission (flame and electric spark) and absorption spectra of inorganic substances. Chiefly laboratory work. ½Mj. Winter Quarter, ———.

13–19. Special Methods in Quantitative Analysis.—Chiefly laboratory work.

13. Electrolytic Methods	½Mj or Mj
14. Special Mineral Analysis	Mj
15. Water Analysis	½Mj
16. Gas Analysis	½Mj
17. Organic Elementary Analysis	½Mj
18. Iron and Steel Analysis	½Mj or Mj
19. Proximate Food Analysis	½Mj or Mj

Prerequisite: course 9. Mj. Summer, Autumn, and Spring Quarters, DR. BARNARD; Winter Quarter, PROFESSOR STIEGLITZ.

20. Assaying.—Fire-assay of gold, silver, and lead ores. Prerequisite: course 9. Winter Quarter, MR. FREAS.

25. Toxicology.—½Mj. Autumn Quarter, PROFESSOR HAINES AND ASSISTANT.

26. Poisons and Their Detection.—A conference and laboratory course. M. Spring Quarter, Second Term, PROFESSOR HAINES.

30. Organic Chemistry.—Prerequisite: Qualitative Analysis. Mj. Autumn Quarter, PROFESSOR NEF.

31. Organic Chemistry.—(Continuation of course 30.) Mj. Winter Quarter, PROFESSOR NEF.

32. Organic Chemistry.—(Continuation of course 31.) M. Spring Quarter, First Term, PROFESSOR NEF.

NOTE.—Courses 30, 31, and 32 form a continuous course, covering the compounds of carbon, including the fatty and the aromatic series. The aim of the courses will be to take up thoroughly the simpler compounds, going with great detail into the chemical behavior, the characteristic reactions, and relationships of the different classes of organic compounds, and considering with great care the synthetic methods by which they can be obtained. Richter's or Bernthsen's *Organic Chemistry* is used as a reference book; but recent literature will, in special cases, be considered in detail.

33. General Organic Chemistry.—Fatty and aromatic series. Prerequisite: course 7. Lectures, 5 hours a week. Mj. (or M. First Term), Summer Quarter, DR. ANDERSON.

34. Elementary Organic Preparations.—Laboratory work, 10 hours a week. This course is arranged to accompany the lectures of course 33. It may be taken without the lectures by students who have had organic chemistry. Prerequisite: course 7. M. or Mj. Summer Quarter, DR. ANDERSON.

35. Organic Preparations.—Laboratory work, 10 or 20 hours a week. Prerequisite: courses 7 and 9, Organic Chemistry (may be taken simultaneously with lectures on Organic Chemistry), and a reading knowledge of German. DM. Summer Quarter, First and Second Terms, DR. ANDERSON; Mj. Autumn, Winter, and Spring Quarters, PROFESSOR NEF.

36. Organic Preparations.—(Continuation of course 35.) DM. Summer Quarter, First and Second Terms, DR. ANDERSON; Mj. Autumn, Winter, and Spring Quarters, PROFESSOR NEF.

37. Organic Preparations.—(Continuation of course 36.) DM. Summer Quarters, First and Second Terms, DR. ANDERSON; Mj. Autumn, Winter, and Spring Quarters, PROFESSOR NEF.

40. Special Chapters of Organic Chemistry.—Lectures. Prerequisite: course 32. M. Spring Quarter, Second Term, PROFESSOR NEF.

41. The Aromatic Series.—Lectures, 2 hours a week. Prerequisite: Organic Chemistry. ½Mj. PROFESSOR STIEGLITZ. [Not given in 1911–12.]

42. The Carbohydrates and the Terpenes and Their Derivatives.—½Mj. Winter Quarter, PROFESSOR STIEGLITZ.

43. Organic Nitrogen Derivatives.—Uric acid series, pyridine, quinone-imides, and phenazine compounds; a discussion of the alkaloids, ptomaines, and organic dye-stuffs. Prerequisite: course 31. ½Mj. PROFESSOR STIEGLITZ. [Not given in 1911–12.]

44. Physical Chemistry Applied to Organic Problems.—Lectures, 2 hours a week. Prerequisite: courses 31 and 60 and 62. ½Mj. PROFESSOR STIEGLITZ. [Not given in 1911–12.]

50. Inorganic Preparations.—Laboratory work. Prerequisite: course 9, and a reading knowledge of German. Mj. or DM. 10 or 20 hours a week. DM. Mj. Summer (Second Term) and Spring Quarters, ASSISTANT PROFESSOR SCHLESINGER; Summer (First Term), Autumn, and Winter Quarters, ASSISTANT PROFESSOR MENZIES.

51. Inorganic Preparations.—(Continuation of course 50.) Mj. or DM. Same schedule as 50.

52. Inorganic Preparations.—(Continuation of course 51.) Mj. or DM. Same schedule as 50.

54. Vapor Pressure: Its Measurement, Applications, and Relationships.—Prerequisite: College Physics and Qualitative Analysis. ASSISTANT PROFESSOR MENZIES. [Not given in 1911–12.]

55. Selected Topics of Inorganic and General Chemistry.—The periodic system, the theory of valence, compounds of metals with one another, molecular compounds, the colloidal condition, and similar topics will be discussed. ½Mj. Lectures only. Summer Quarter, ASSISTANT PROFESSOR SCHLESINGER.

56. Advanced Inorganic Chemistry.—Two lectures a week on selected topics. Prerequisite: course 7. ———. [Not given in 1911–12.]

57. The Chemistry of Photography.— ———. [Not given in 1911–12.]

60. Elementary Physical Chemistry, I.—Lectures on laws of gases, atomic theory, kinetic theory, optical activity, phase rule, and related topics. Prerequisite: Physics 1 and Chemistry 6. ½Mj. Spring Quarter, PROFESSOR McCOY.

61. Elementary Physical Chemistry, II.—Lectures on laws of solution, ionic theory, electro-chemistry, reaction velocity, chemical equilibrium, and related topics. M. Summer Quarter, First Term, PROFESSOR McCOY.

62. Physico-Chemical Measurements, I.—Laboratory course on the determination of vapor densities, molecular weights by freezing and boiling-point methods, degrees of ionization by conductivity method, transference numbers, optical activity, and reaction velocity. Prerequisite: Physics 1, Chemistry 8. Course 60 should accompany or precede this course. M. First or Second Term, Summer Quarter, or ½Mj. for the quarter; ½Mj. Spring Quarter, PROFESSOR McCOY.

63. Physico-Chemical Measurements, II.—Laboratory course. Continuation of 62, including a large variety of typical determinations. Prerequisite: Physics 3 and Chemistry 62. Course 65 should accompany or precede this course. Mj. or DM. Summer, Autumn, and Spring Quarters, PROFESSOR McCOY.

64. Physico-Chemical Measurements, III.—Laboratory course. Continuation of course 63. Mj. or DM. Summer, Autumn, and Spring Quarters, PROFESSOR McCOY.

65. Chemical Dynamics.—Advanced course based on *Nernst's Theoretical Chemistry*. Prerequisite: courses 54, 60, 61, and Calculus. ½Mj. Summer Quarter, PROFESSOR McCOY.

67. Electro-Chemistry.—Prerequisite: course 60, and Mathematics, 15. ½Mj. PROFESSOR McCOY. [Not given in 1911–12.]

68. Radio-activity and the Nature of Matter.—Lectures. Prerequisite course 60. ½Mj. Autumn Quarter, PROFESSOR McCOY.

69. Laboratory Course in Radio-activity.—To accompany or follow course 68. ½Mj. or M. Summer, Autumn, and Spring Quarters, PROFESSOR McCOY.

71. The Atomic Theory.—Prerequisite: course 8. ½Mj. Spring Quarter, PROFESSOR McCOY.

81. History of Chemistry.—Two hours a week. ½Mj. Winter Quarter, ———.

82. Club meetings.—Meetings will be held twice a month. They may be attended by anyone interested. The subjects for the meetings will be announced at least one week in advance. Summer, Winter, and Spring Quarters.

83. The Teaching of Chemistry.—A series of conferences. ½Mj. Spring Quarter, PROFESSOR ———.

85. The Chemistry and Preparation of Medicinal Drugs.—½Mj. Spring Quarter, PROFESSOR HAINES.

90–94. Research Work.—These courses will include from 30 to 40 hours a week of laboratory work, under the special direction of some one of the instructors in the Department. It is expected that research work for a Doctor's thesis will require 4–6 quarters (4–6 DMj.). Before being admitted to research, a candidate must satisfy the instructors of the Department that his previous training has been sufficient.

90. Research in Organic Chemistry.—Autumn, Winter, and Spring Quarters, PROFESSOR NEF.

91. Research in Organic and Physico-Organic Chemistry.—Autumn, Winter, and Spring Quarters, PROFESSOR STIEGLITZ.

92. Research in Physical Chemistry.—Summer, Autumn, and Spring Quarters, PROFESSOR McCOY.

93. Research in General Chemistry.—Summer, Autumn, and Winter Quarters, ASSISTANT PROFESSOR MENZIES.

94. Research in Inorganic and Physical Chemistry.—Summer, Autumn, and Winter Quarters, ASSISTANT PROFESSOR SCHLESINGER.

95. Independent Research.—Summer, Autumn, Winter, and Spring Quarters.

96. Masters' Theses in Analytical Chemistry.—DR. BARNARD.

DOCTORS OF PHILOSOPHY OF THE UNIVERSITY OF CHICAGO

MATHEMATICS

1896 JOHN IRWIN HUTCHINSON, Professor of Mathematics, Cornell University.
On the Reduction of Hyperelliptic Functions ($p=2$) to Elliptic Functions by a Transformation of the Second Degree.

LEONARD EUGENE DICKSON, Professor of Mathematics, The University of Chicago.
The Analytic Representation of Substitutions.

1898 HERBERT ELLSWORTH SLAUGHT, Associate Professor of Mathematics, The University of Chicago.
The Cross-ratio Group of 120 Quadratic Cremona Transformations of the Plane.

1899 JOHN ANTHONY MILLER, Professor of Mathematics and Astronomy, Swarthmore College.
Concerning Certain Elliptic Modular Functions of Square Rank.

1900 GILBERT AMES BLISS, Associate Professor of Mathematics, The University of Chicago.
The Geodesic Lines on the Anchor Ring.

GEORGE LINCOLN BROWN, Professor of Mathematics, South Dakota Agricultural College.
A Ternary Linear Substitution Group of Order 3.360.

WILLIAM GILLESPIE, Professor of Mathematics, Princeton University.
On the Reduction of Hyperelliptic Integrals ($p=3$) to Elliptic Integrals by Transformation of the Second and Third Degree.

DERRICK NORMAN LEHMER, Assistant Professor of Mathematics, University of California.
Asymptotic Evaluation of Certain Totient Sums.

JOHN HECTOR MCDONALD, Assistant Professor of Mathematics, University of California.
On the System of a Binary Cubic and Quadratic and the Reduction of Hyperelliptic Integrals of Genus Two to Elliptic Integrals by a Transformation of the Fourth Order.

ERNEST BROWN SKINNER, Assistant Professor of Mathematics, University of Wisconsin.
Ternary Monomial Substitution Groups of Finite Order with Determinant $\neq 0$.

1901 WILLIAM FINDLAY, Professor of Mathematics, McMaster University.
The Sylow Subgroups of the Symmetric Group.

THOMAS MILTON PUTNAM, Assistant Professor of Mathematics, University of California.
The Quaternary Linear Homogeneous Group and the Ternary Linear Fractional Group.

1903 OSWALD VEBLEN, Professor of Mathematics, Princeton University.
A System of Axioms for Geometry.

1904 WILLIAM HENRY BUSSEY, Assistant Professor of Mathematics, University of Minnesota.
Generational Relations for the Abstract Group Simply Isomorphic with the Group LF(2; p^n).

1904 Herbert Edwin Jordan, Instructor in Mathematics, Michigan College of Mines.
Group Characters of Various Linear Groups.

Arthur Whipple Smith, Assistant Professor of Mathematics, Colgate University.
Symbolic Treatment of Differential Geometry.

1905 Thomas Emory McKinney, Professor of Mathematics, University of North Dakota.
Concerning a Certain Type of Continued Fractions Depending on a Variable Parameter.

Robert Lee Moore, Instructor in Mathematics, Northwestern University.
Sets of Metrical Hypotheses for Geometry.

1906 William Raymond Longley, Assistant Professor of Mathematics, Yale University.
A Class of Periodic Orbits of an Infinitesimal Body Subject to the Attraction of n Finite Bodies.

Arthur Ranum, Instructor in Mathematics, Cornell University.
The Group of Classes of Congruent Matrices with Application to the Group of Isomorphisms of Any Abelian Group.

Anthony Lispenard Underhill, Assistant Professor of Mathematics, University of Minnesota.
Invariants under Point Transformations in the Calculus of Variations.

Buzz M. Walker, Professor of Mathematics and Director of School of Engineering, Mississippi Agricultural and Mechanical College.
On the Resolution of Higher Singularities of Algebraic Curves into Ordinary Double Points.

1907 George David Birkhoff, Professor of Mathematics, Princeton University
Asymptotic Properties of Certain Ordinary Differential Equations, with Applications to Boundary Value and Expansion Problems.

Robert Lacey Börger, Instructor in Mathematics, University of Illinois.
On the Determination of Ternary Linear Groups in the Galois Field of Order p^2.

Louis Ingold, Instructor in Mathematics, University of Missouri.
Vector Interpretation of Symbolic Parameters.

Nels Johann Lennes, Instructor in Mathematics, Columbia University.
Curves in Non-metrical Analysis Situs with Applications to the Calculus of Variations and Differential Equations.

Frederick William Owens, Instructor in Mathematics, Cornell University.
The Introduction of Ideal Elements and Construction of Projective n-space in Terms of a Planar System of Points.

Norman Richard Wilson, Associate Professor of Mathematics, University of Manitoba.
Isoperimetrical Problems Which are Reducible to Non-isoperimetrical Problems.

1908 Mary Emily Sinclair, Instructor in Mathematics, Oberlin College.
On a Compound Discontinuous Solution Connected with the Surface of Revolution of Minimum Area.

1909 Thomas Buck, Instructor-elect in Mathematics, University of California.

Herbert Earle Buchanan, Assistant Professor-elect of Astronomy in Carleton College.

Arnold Dresden, Instructor in Mathematics, The University of Wisconsin.
The Second Derivatives of the Extremal-Integral.

Harris Franklin MacNeish, Instructor in Mathematics, Yale University.
Linear Polars of the k-hedron in n-space.

1910 Anna Johnson Pell, Instructor-elect in Mathematics, Mount Holyoke College.
Biorthogonal Systems of Functions with Applications to the Theory of Integral Equations.

Theophil Henry Hildebrandt, Instructor in Mathematics, University of Michigan.
A Contribution to the Foundations of Fréchet's Calcul Fonctionnel.

Egbert J. Miles, Instructor-elect in Mathematics, Yale University.
The Absolute Minimum of a Definite Integral in a Special Field.

Richard Philip Baker, Assistant Professor of Mathematics, State University of Iowa.
The Problem of the Angle-Bisectors.

William Hunt Bates, Assistant Professor of Mathematics, Purdue University.
An Application of Symbolic Methods to the Treatment of Mean Curvatures in Hyper-Space.

Arthur Dunn Pitcher, Assistant Professor of Mathematics, University of Kansas.
The Interrelation of Eight Fundamental Properties of Classes of Functions.

Marion Ballantyne White, Assistant Professor of Mathematics, University of Kansas.
The Dependence of the Focal Point on Curvature in Space Problems of the Calculus of Variations.

MATHEMATICAL ASTRONOMY

1900 Forest Ray Moulton, Associate Professor of Astronomy, The University of Chicago.
Periodic Oscillating Satellites.

1903 William Albert Hamilton, Professor of Astronomy, Beloit College.
The True Radii of Convergence for Expansions as Power Series in the Time, in the Case of Parabolic Motion.

1904 Arthur Constant Lunn, Assistant Professor of Applied Mathematics, The University of Chicago.
The Differential Equations of Dynamics.

1905 Delonzo Tate Wilson, Assistant Professor of Mathematics, Case School of Applied Science.
Work on Minor Planets.

1906 Frank Loxley Griffin, Professor-elect of Mathematics, Reed Institute, Portland, Ore.
Certain Periodic Orbits of k Finite Bodies Revolving about a Relatively Large Central Mass.

1908 William Duncan MacMillan, Instructor in Mathematics and Astronomy, The University of Chicago.
Periodic Orbits about an Oblate Spheroid.

PHYSICS

1897 Gordon Ferry Hull, Professor of Physics, Dartmouth College.
On the Use of the Interferometer in the Study of Electric Waves.

Isabel Stone, Principal of American School for Girls, Rome, Italy.
On the Electrical Resistance of Thin Films.

1898 Edwin Sheldon Johonnott, Associate Professor of Physics, Rose Polytechnic Institution.
Thickness of the Black Spot in Liquid Films.

1899 Henry Gordon Gale, Assistant Professor of Physics, The University of Chicago.
On the Relation between Density and Index of Refraction of Air.

1900 Robert Francis Earhart, Assistant Professor of Physics, Ohio State University.
The Sparkling Potentials between Plates at Small Distances.

1901 Fritz Reichmann, Practical Physicist, Troy, N.Y.
The Capacities of Air Condensers for Very Small Distances between the Plates.

1902 Frank Baldwin Jewett, Electrical Engineer, 15 Dey St., New York City, N.Y.
A New Method of Determining the Vapor-Density of Metallic Vapors.

1904 Thomas Eaton Doubt, Associate Professor of Physics, Armour Institute of Technology, Chicago, Ill.
The Effect of Intensity upon the Velocity of Light.

Fannie Cornelia Frisbee (Mrs. Frank B. Jewett), New York City, N.Y.
The Effects of Pressure on Magnetic Induction.

Thomas Carlyle Hebb, Professor of Physics, State Normal School, Marquette, Mich.
The Velocity of Sound.

1905 Frederic Lendhall Bishop, Professor of Physics, University of Pittsburgh, Pittsburgh, Pa.
The Thermal Conductivity of Lead.

Glenn Moody Hobbs, Secretary of the American School of Correspondence, Chicago, Ill.
The Relation between P.D. and Spark-Length for Small Values of the Latter.

Carelton John Lynde, Professor of Physics, MacDonald College, Quebec, Can.
The Effect of Pressure on Surface Tension.

1906 William Richards Blair, Government Observatory, Mt. Weather, Va.
The Change of Phase Due to the Passage of Electric Waves through Thin Films.

Lawrence Emery Gurney, Associate Professor of Physics, University of Idaho.
The Viscocity of Water at Very Low Rates of Shear.

1907 George Winchester, Professor of Physics, Washington and Jefferson College, Washington, Pa.
Discharge of Electricity from Metals under the Influence of Ultra-violet Light.

Oliver Charles Clifford, Assistant Professor of Physics, Armour Institute of Technology, Chicago, Ill.
Susceptibility of Copper and Tin and Their Alloys.

1909 Newland Farnsworth Smith, Professor of Physics, Central College, Danville, Ky.
Effect of Tension on Thermal and Electrical Conductivity.

William Ross Ham, Professor of Physics, Pennsylvania State College, State College, Pa.
The Polarization of Primary X-Rays.

Charles Albert Proctor, Assistant Professor of Physics, Dartmouth College, Hanover, N.H.
The Variation of $\frac{e}{m}$ with Speed in the Case of Cathode Rays.

1910 John Mathias Kuehne, Associate Professor of Physics, University of Texas, Austin, Tex.
The Electrostatic Effect of a Changing Magnetic Field.

Louis Begeman, Professor of Physics, Iowa State Teachers' College.
The Determination of "E" by the Cloud Method.

Ansel Alphonso Knowlton, Professor of Physics, Utah State University.
Preparation and Testing of Hensler Alloys.

1910 J. Harry Clo, Assistant in Physics, The University of Chicago.
The Effect of Temperature upon the Ionization of Gas.

James Remus Wright, Associate Professor of Physics, University of the Philippines, Manila.
Photo-electric Effects of Aluminum as a Function of the Wave-Length of the Incident Light.

1911 Harvey Fletcher, Professor of Physics, Brigham Young University.
A Verification of the Theory of Brownian Movements and a Direct Determination of the Value of Ne for Gaseous Ionization.

CHEMISTRY

1894 Adolph Bernhard, State Normal School, La Crosse, Wis.
Ueber die Einführung von Acylen in den Benzoylessigather.

Warren Rufus Smith, Professor of Chemistry, Lewis Institute, Chicago, Ill.
On the Addition Products of the Aromatic Isocyanides.

1896 Bernard Conrad Hesse, Consulting Chemist, New York City.
On Malonic Nitrile and Some of its Derivatives.

Samuel Ellis Swartz, Professor of Chemistry and Physics, Fairmount College, Wichita, Kan.
The Action of Sodium Ethylate on Amide Bromides.

1897 James Bert Garner, Professor of Chemistry, Wabash College, Crawfordsville, Ind.
Condensations with Benzoin by Means of Sodium Ethylate.

Lauder William Jones, Professor of Chemistry, University of Cincinnati.
On Salts of Nitroparaffine and Acylated Derivatives of Hydroxylamine.

1898 Frank Burnett Dains, Professor of Chemistry, Washburn College, Topeka, Kan.
On the Isourea Ethers and Other Derivatives of Ureas.

Otto Folin, Associate Professor of Biological Chemistry, Harvard Medical School, Boston, Mass.
On Urethanes.

Elizabeth Jeffreys, Professor of Chemistry, Pritchett College, Glasgow, Mo.
On Undecylamine and Pentadecylamine and the Preparation of the Higher Amines of the Alipathic Series.

Herbert Newby McCoy, Professor of Chemistry, The University of Chicago Chicago, Ill.
On the Hydrochlorides of Carbo-phenylimido Derivatives.

1899 John Charles Hessler, Professor of Chemistry, James Millikin University, Decatur, Ill.
On Alkyl Malonic Nitriles and Their Derivatives.

William McPherson, Professor of Chemistry, Ohio State University, Columbus, O.
On the Nature of the Oxyazo Compounds.

James Harvey Ransom, Professor of General Chemistry, Purdue University, Lafayette, Ind.
On the Molecular Rearrangement of o-Aninophenylethyl Carbonate to o-Oxyphenylurethane.

1900 Henry Chalmers Biddle, Associate Professor of Chemistry, University of California.
Ueber Derivate des Isuretins der Formhydroxamsäure und ihre Beziehungen zur Knallsäure.

1901 Ralph Harper McKee, Professor of Chemistry, University of Maine, Orono, Me.
On the Oxygen Ethers of the Ureas: Methyl- and Ethylisourea.

1902 Solomon Farley Acree, Associate Professor of Chemistry, Johns Hopkins University, Baltimore, Md.
On Sodium Phenyl and the Action of Sodium on Ketones.

1902 WALLACE APPLETON BEATTY, ———.
The Action of Carbon Monoxide on Sodium Alcoholates Alone and in the Presence of Salts of Fatty Acids.

EUGENE PAUL SCHOCH, Associate Professor of Chemistry, University of Texas, Austin, Tex.
The Red and the Yellow Mercuric Oxides and the Mercuric Oxychlorides.

EDWIN EMERY SLOSSON, Literary Editor of *The Independent*, New York City.
On Acylhalogenamine Derivatives and the Beckmann Rearrangement.

1903 HENRY TABOR UPSON, Vice-President and Manager of Pease Oil Co., Buffalo, N.Y.
The Molecular Rearrangement of Aminophenylalkyl Carbonates.

1904 MAXWELL ADAMS, Professor of Chemistry, State University, Reno, Nev.
On Some Hydroxylamine Compounds.

RAYMOND FOSS BACON, Bureau of Chemistry, Department of Agriculture, Washington, D.C.
On the Reactions of Sodium Benzhydrol.

WILLIAM MCAFEE BRUCE, Arkansas Agricultural College.
On the Oxygen Ethers of Urea.

NELLIE ESTHER GOLDTHWAITE, Research Assistant, University of Illinois, Champaign, Ill.
On Substituted Benzhydrol Derivatives and Bromcyanacetic Ether.

OSWIN W. WILLCOX, Technical Chemist, New York, N.Y.
On the Reactions of Ethyl Chlorsulphonate.

1905 WILLIAM LLOYD EVANS, Assistant Professor of Chemistry, Ohio State University, Columbus, O.
On the Behavior of Benzoyl Carbinol towards Alkalies and Oxidizing Agents.

WILLIAM MCCRACKEN, Professor of Natural Sciences, State Normal School, Kalamazoo, Mich.
Study in Catalysis. V. The Catalysis of Imidoesters.

HERMANN SCHLESINGER, Assistant Professor of Chemistry, The University of Chicago.
Studies in Catalysis. VI. The Catalysis of Imidoesters.

1906 ROY HUTCHINSON BROWNLEE, Assistant Superintendent, Standard Oil Co., Whiting, Ind.
On Precipitated Sulphur.

CHARLES M. CARSON, Professor of Chemistry, University of New Brunswick.
On Amorphous Sulphur: Further Study of the Two Forms of Liquid Sulphur as Dynamic Isomers.

HENRY MAX GOETTSCH, Assistant Professor of Technical Chemistry, University of Cincinnati, Cincinnati, Ohio.
The Absorption Coefficients of Uranium Compounds.

WILLIS STOSE HILPERT, Chemist, American Medical Association, Chicago, Ill.
Stereoisomeric Chlorimido Acid Esters.

JAMES WRIGHT LAWRIE, Chemist, Pullman Co., Chicago, Ill.
The Chemistry of the Acetylidene Compounds.

ANDREW FRIDLEY MCLEOD, Instructor in Chemistry, Beloit College, Beloit, Wis.
On Aldol, Pentaerythrose, and the Action of Copper Acetate on the Hexoses.

1907 EDITH ETHEL BARNARD, Instructor in Chemistry, The University of Chicago.
The Catalysis of Imidoesters as Affected by the Presence of Non-electrolytes and Electrolytes.

1907 KATHERINE BLUNT, Instructor in Chemistry, Vassar College, Poughkeepsie, N.Y.
The Formation of Amidines.

WILLEY DENIS, Assistant Chemist, United States Department of Agriculture, Washington, D.C.
On the Behavior of Various Aldehydes, Ketones, and Alcohols Toward Oxidizing Agents.

ROBERT ANDERSON HALL, Assistant Professor of Chemistry, University of North Carolina, Chapel Hill, N.C.
The Action of Ammonia on Isourea Esters.

LOUIS ALLEN HIGLEY, Professor of Chemistry, Westminster College, Mo.
On the Behavior of Sodium and Sodium Alcoholates toward Various Esters.

WILLIAM HORACE ROSS, Assistant Chemist, Agricultural Experiment Station, University of Arizona, Tucson, Ariz.
On the Relation between the Radio-activity and the Composition of Thorium and Uranium Minerals.

LOUIS A. TEST, Associate Professor of Chemistry, Missouri School of Mines, Rolla, Mo.
The Rearrangement of o-Amino Phenyl Esters.

1908 GEORGE CROMWELL ASHMAN, Professor of Chemistry, Bradley Institute, Peoria, Ill.
Studies in Radioactivity.

1909 ERNEST ANDERSON, Research Instructor, The University of Chicago.
The Action of Fehling's Solution on *d*-Galactose.

WILLIAM WELDON HICKMAN, Professor of Chemistry, Assuit College, Assuit, Egypt.
The Catalysis of Imido-Esters.

WINFORD LEE LEWIS, Assistant Professor of Chemistry, Northwestern University.
The Action of Fehling's Solution on Maltose.

PETER POWELL PETERSON, Instructor in Soil Investigations, University of Wisconsin.
Stereoismerism of Chlorimido-Ketones.

LEMUEL CHARLES RAIFORD, Instructor in Chemistry, The University of Chicago.
Chlorimido Quinones.

HERMAN AUGUSTUS SPOEHR, Chemical Plant Physiologist, Carnegie Institution.
The Behavior of the Ordinary Hexoses toward Hydrogen Peroxide in the Presence of Alkaline Hydroxides as Well as of Various Iron Salts.

1910 ALAN W. C. MENZIES, Assistant Professor of Chemistry, The University of Chicago.
Studies in Vapor Pressure.

EMMA PERRY CARR, Professor of Chemistry, Mount Holyoke College.
The Aliphatic Imidoesters.

ELBERT EDWIN CHANDLER, Professor of Chemistry, Occidental College, Los Angeles, Cal.
Ionization Constants of the Second Hydrogen Ion of Dibasic Acids.

IRA HARRIS DERBY, Assistant Professor of Chemistry, University of Minnesota.
Studies in Catalysis of Imidoesters, IV.

STEWART JOSEPH LLOYD, Associate Professor of Chemistry and Metallurgy, University of Alabama.
Studies in Radioactivity.

1910 JOHN COLIN MOORE, Instructor in Chemistry, Lake View High School, Chicago.
The Action of Water on Acyl Isoureas.

WILLIAM CABLER MOORE, Instructor in Chemistry, Columbia University.
Studies in Organic Amalgams.

FRED WILBERT UPSON, Instructor in Chemistry, University of Cincinnati.
On the Action of Normal Barium Hydroxide on d. Glucose and d. Galactose.

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1914/15

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The University of Chicago
FOUNDED BY JOHN D. ROCKEFELLER

CIRCULAR OF THE DEPARTMENTS OF

MATHEMATICS, ASTRONOMY AND ASTROPHYSICS, PHYSICS CHEMISTRY

1914

THE UNIVERSITY OF CHICAGO PRESS
CHICAGO, ILLINOIS

CALENDAR FOR THE YEAR 1914–15

1914

June 7	Sunday	Convocation Sunday
June 8	Monday	College Day
June 9	Tuesday	Summer Convocation
June 10	Wednesday	Quarterly Examinations
June 11	Thursday	Quarterly Examinations
June 12	Friday	Quarterly Examinations
June 12	Friday	Spring Quarter ends
June 15	*Monday*	*Summer Quarter begins*
June 15–20		Examinations of College Entrance Examination Board
July 4	Saturday	Independence Day: a holiday
July 11	Saturday	Examinations for removal of conditions and incompletes incurred during Spring Quarter
July 22	Wednesday	Examinations for the First Term of Summer Quarter First Term of Summer Quarter ends
July 23	Thursday	Second Term of Summer Quarter begins
July 25	Saturday	Efficiency Tests in Modern Languages
Aug. 23	Sunday	Convocation Sunday
Aug. 28	Friday	Examinations for Second Term of Summer Quarter Autumn Convocation Second Term of Summer Quarter ends
Sept. 8–11		Entrance Examinations
Sept. 29	Tuesday	Examinations for removal of conditions and incompletes for all students returning for Autumn Quarter
Oct. 1	*Thursday*	*Autumn Quarter begins*
Nov. 26	Thursday	Thanksgiving Day: a holiday
Nov. 28	Saturday	Efficiency Tests in Modern Languages
Dec. 20	Sunday	Convocation Sunday
Dec. 19	Saturday	Quarterly Examinations
Dec. 21	Monday	Quarterly Examinations
Dec. 23	Wednesday	Quarterly Examinations
Dec. 22	Tuesday	Convocation Day
Dec. 23	Wednesday	Autumn Quarter ends

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Jan. 4	*Monday*	*Winter Quarter begins*
Jan. 30	Saturday	Examinations for removal of conditions and incompletes
Feb. 12	Friday	Lincoln's Birthday: a holiday
Feb. 22	Monday	Washington's Birthday: a holiday
Feb. 27	Saturday	Efficiency Tests in Modern Languages
Mar. 14	Sunday	Convocation Sunday
Mar. 16	Tuesday	Spring Convocation
Mar. 17	Wednesday	Quarterly Examinations
Mar. 18	Thursday	Quarterly Examinations
Mar. 19	Friday	Quarterly Examinations
Mar. 20–28		Quarterly Recess
Mar. 29	*Monday*	*Spring Quarter begins*
April 16–17		Annual Conference with Co-operating Schools
April 24	Saturday	Examinations for removal of conditions and incompletes incurred during Winter Quarter
May 29	Saturday	Efficiency Tests in Modern Languages
June 13	Sunday	Convocation Sunday
June 14	Monday	College Day
June 15	Tuesday	Summer Convocation
June 16	Wednesday	Quarterly Examinations
June 17	Thursday	Quarterly Examinations
June 18	Friday	Quarterly Examinations
June 18	Friday	Spring Quarter ends

OFFICERS OF ADMINISTRATION

HARRY PRATT JUDSON, President of the University, Harper Memorial Library, Room W11.

WALTER A. PAYNE, University Recorder and University Examiner, Cobb Lecture Hall, Room 5A.

CHARLES RICHMOND HENDERSON, University Chaplain, Harper Memorial Library, Room M16.

DAVID ALLAN ROBERTSON, Secretary to the President, Harper Memorial Library, Room W13.

ERNEST DEWITT BURTON, Director of the University Libraries, Harper Memorial Library, Room M27.

JAMES ROWLAND ANGELL, Dean of the Faculties of Arts, Literature, and Science, Cobb Lecture Hall, Room 6A.

ALBION WOODBURY SMALL, Dean of the Graduate School of Arts and Literature, Cobb Lecture Hall, Room 6A.

ROLLIN D. SALISBURY, Dean of the Ogden (Graduate) School of Science, Cobb Lecture Hall, Room 6A.

MARION TALBOT, Dean of Women, Cobb Lecture Hall, Room 14A.

LEON CARROLL MARSHALL, Dean of the Senior Colleges, and Dean of the College of Commerce and Administration, Cobb Lecture Hall, Room 10A.

HENRY GORDON GALE, Dean of Science in the Colleges, Cobb Lecture Hall, Room 8A.

ROBERT MORSS LOVETT, Dean of the Junior Colleges, Cobb Lecture Hall, Room 9A.

JAMES WEBER LINN, PERCY HOLMES BOYNTON, Ellis Hall; ELIZABETH WALLACE, FRANK JUSTUS MILLER, Lexington Hall: Deans in the Junior Colleges.

SOPHONISBA PRESTON BRECKINRIDGE, Assistant Dean of Women, Cobb Lecture Hall, Room 14A.

NATHANIEL BUTLER, Director of Co-operation with Secondary Schools, Cobb Lecture Hall, Room 16A.

GENERAL INFORMATION

The organization of the University includes: the Graduate School of Arts and Literature; the Ogden (Graduate) School of Science; the Colleges (Senior, last two years, and Junior, first two years) of Arts, Literature, and Science; the Divinity School, the Law School, Courses in Medicine, the School of Education, the College of Commerce and Administration.

Faculty and equipment.—The faculty numbers three hundred and thirty-seven; the libraries contain 402,503 volumes. The University owns ninety acres of land in Chicago and has thirty-five buildings.

Location of the University.—The University grounds lie on both sides of the Midway Plaisance between Washington and Jackson parks, six miles south of the center of Chicago. Electric cars, elevated trains, and the Illinois Central suburban service reach all railway stations. Mail and baggage service is provided at the Information Office of the University.

The University year is divided into quarters: the Autumn (October, November, December); the Winter (January, February, March); the Spring (April, May, to the middle of June); the Summer (from the middle of June, July, August). For the year 1914–15 the exact dates for the opening of the four quarters are: Summer Quarter, June 15, 1914; Autumn Quarter, October 1, 1914; Winter Quarter, January 4, 1915; Spring Quarter, March 29, 1915. Students are admitted at the opening of each quarter; graduation exercises are held at the close of each quarter.

The unit of work and of credit is a *major*, i.e., a course of instruction involving four or five recitations or lecture hours per week for a full quarter, or double that number of hours for a term of six weeks. A *minor* is one-half a major. Normal work is three majors per quarter, or nine per year of three quarters.

Degrees.—The University confers in the Graduate Schools the degrees of Doctor of Philosophy and of Master of Arts and of Science; in the Colleges, the degrees of Bachelor of Arts, of Science, and of Philosophy; in the Divinity School, the degrees of Bachelor of Divinity, of Master of Arts, and of Doctor of Philosophy; in the Law School, the Degrees of Doctor of Law and Bachelor of Laws; in the School of Education, the degrees of Bachelor of Arts in Education, of Philosophy in Education, and of Science in Education; in the College of Commerce and Administration, the degree of Bachelor of Philosophy.

Fellowships, scholarships, student service, etc.—By virtue of endowments and special appropriations, fellowships and scholarships and service afford stipends or tuition to a number of able and deserving students. The University also maintains a bureau for securing outside employment.

FEES FOR MATRICULATION, TUITION, ETC.

A. *Matriculation fee.*—The matriculation fee is $5, and is required of every student on entrance to the University.

B. *Tuition fee.*—1. The tuition fee is $40 per quarter for regular work (three majors or their equivalent); there is no reduction to those taking only two majors. 2. A reduction is made in case of students taking only one major (or equivalent), one-half the full tuition fee being charged. 3. *All tuition and laboratory fees are due on or before the first day of each quarter, and payable without extra fee up*

to the end of the fifth day of the quarter. All fees are payable to the Cashier, Press Building, Room 1.

C. *Fines, etc.*—For failure to pay tuition fees within the first five days of the quarter a fee of $5 is added to the bill.

D. *Laboratory fee.*—Students in all laboratory courses pay a laboratory fee of $5 a major. Ten dollars ($10) is the maximum charge for laboratory work in any one department (M. and DMj. courses will be charged in proportion). In addition to the regular laboratory fee, students in Chemistry will procure a coupon ticket, entitling them to $5 worth of laboratory material. Students doing laboratory work in the departments of Zoölogy, Anatomy, Physiology, Botany, Pathology, and Hygiene and Bacteriology are required to purchase a laboratory supply and breakage ticket at the office of the Cashier, and file the same at the laboratory supply store, Room 10, Botany Building.

E. *A small material fee* is charged in certain courses in Economics.

F. *Gymnasium locker fee.*—For the use of a locker in the dressing-room of the gymnasium a fee of $1 per quarter is charged. A small fee is also charged for the use of the tennis courts.

G. *Graduation fee.*—The general graduation fee, including diploma, is $10. The graduation fee for Doctors, including diploma and hood, is $15. In the case of students taking the certificate of a two years' course the charge is $5.

ROOMS, BOARD, AND GENERAL EXPENSES

There are ten dormitories in the University quadrangles. Two of these are reserved for the students of the Divinity School, and five are for women.

The cost of rooms in the dormitories is from $20 to $74 per quarter of twelve weeks. This includes heat, light, and care. Each hall for women has separate dining-hall and parlors. The cost of table board in these halls is $4.50 per week.

All applications for rooms, or for information concerning rooms and board within or without the quadrangles, should be made to the Cashier.

The following table will furnish an estimate of the annual expenses for thirty-six weeks of a student in the University, residing within the quadrangles:

	Lowest	Average	Liberal
University bill, tuition	$120.00	$120.00	$120.00
Rent and care of room	60.00	105.00	225.00
Board	135.00	162.00	225.00
Laundry	15.00	25.00	35.00
Textbooks and stationery	10.00	20.00	50.00
Total	$340.00	$432.00	$655.00

It is believed that students who find it necessary to reduce expenses below the lowest of these estimates can do so. By application to the Housing Inspector, rooms outside the quadrangles, furnished, heated, lighted, and cared for, may be obtained at from $1.50 a week upward. This rate is obtainable, as a rule, when two or more students room together. Room and board in private houses are offered from $6 per week upward. The University Commons, Hutchinson Hall, offers to students meals *à la carte*. Lexington Commons for women offers meals *à la carte* during the Autumn, Winter, and Spring quarters. During the Summer Quarter the University Commons is open to both men and women.

FELLOWSHIPS AND SCHOLARSHIPS

The Trustees award annually about one hundred Fellowships in the Graduate Schools. These Fellowships range in value from $120, the tuition fees of a student for three quarters, to $520, that is, $400 in addition to the tuition fees for three quarters. A limited number of Scholarships, covering a part or all of the tuition fees for three quarters, are also awarded annually.

Candidates for these Fellowships and Scholarships should send to the Deans of the Graduate Schools a record of their previous work and distinctions, degrees and past courses of study, with copies of their written or printed work in the field of the department in which application is made. Applications must be received at the Deans' offices *not later than March 1 of each year*, in order to be considered for the following year. Appointments will be made early in April.

Fellows may be called upon for assistance in teaching in the University, or for kindred work; but in no case will they be expected or permitted to devote more than one-sixth of their time to such service. Fellows will not engage in outside work for compensation, unless by permission of the President. Except in rare cases, students will not be appointed to Fellowships until they have done at least one year of graduate work.

In addition to the Scholarships mentioned above, one graduate Scholarship, yielding a sum sufficient to pay the annual tuition fees, is annually awarded to the best student in each department graduated from the University of Chicago during the preceding year.

A Scholarship yielding the amount of the tuition fees for three quarters ($120) is annually awarded in each department offering Junior College work, to the best student receiving the Associate's title during the preceding year.

Full particulars concerning higher degrees, Fellowships, Scholarships, and other matters of interest to graduate students will be found in the *Circular of Information* of the Colleges and Graduate Schools, which will be sent upon application.

AID TO STUDENTS

Besides Fellowships and Scholarships various kinds of assistance are offered to those who need help, under the following heads: (1) Prizes; (2) University Service; (3) Loans by the Students' Fund Society, and (4) Outside Employment. The position of the University in a large city brings the decided advantage of providing many opportunities for employment. Through the University Employment Bureau many students are able to secure all of the outside employment for which they have time. For further details applicants should send for the circular, *Assistance to Students at the University of Chicago.*

DEGREES

Graduate study may lead to a Master's or to a Doctor's degree under the conditions specified below:

I. THE MASTER'S DEGREE

Two degrees are conferred, viz., *Master of Arts* and *Master of Science.*

1. *Candidacy.*—Any member of the Graduate Schools who has been in attendance one quarter or more, and whose undergraduate course is equivalent to that required for a corresponding Bachelor's degree in the University of

Chicago,[1] may, on recommendation by the department or departments in which he is working, be enrolled, by vote of the Faculties of the Graduate Schools, as a candidate for a Master's degree. The student is required to get from the office of the Deans of the Graduate Schools, and have filled out, a form by means of which his application for candidacy must be presented to the Faculties of the Graduate Schools. Admission to candidacy must precede the conferring of the degree by at least two months.

2. *Requirements.*—Students thus accepted as candidates will be given a Master's degree on fulfilment of the following requirements:

a) At least three quarters' residence at the University.

b) At least eight majors of graduate work. These eight majors need not be all in one department, but must be selected according to some rational plan approved by the Deans of the Graduate Schools at least six months before the degree is conferred. The individual courses must receive the approval of the heads of the departments concerned.

c) A satisfactory dissertation on a subject approved by one of the departments in which the work is done.[2]

d) The delivery of five printed or typewritten copies, including one bound copy, of the dissertation to the University Library, at least one week before the Convocation at which the degree is to be conferred.

e) A satisfactory examination on the work taken for the degree.

f) No course completed with a grade below C will count toward the Master's degree.

II. THE DEGREE OF DOCTOR OF PHILOSOPHY

1. *Candidacy.*—Any member of the Graduate Schools who has been in attendance one quarter or more, whose undergraduate course is equivalent to that required for a Bachelor's degree in the University of Chicago,[3] whose thesis subject has been accepted by the principal department, and who has a reading knowledge of French and German (*which must be officially certified by those departments* at least nine months before the examination in the principal department) may, on recommendation by the principal department in which he wishes to take his degree, be enrolled, by vote of the Faculties of the Graduate Schools, as a candidate for the Doctor's degree. Admission to candidacy must precede the conferring of the degree by at least two months.

2. *Requirements.*—Students accepted as candidates will be given the Doctor's degree on the fulfilment of the following requirements:

a) At least three years of resident work at the University, in pursuance of an accepted course of study (see 5 and 6 below). The course in question must include one principal, and either one or two secondary subjects. The amount of work required in the secondary subject or subjects is nine majors.

b) A satisfactory final examination upon the work done in preparation for the degree.

[1] Attention is particularly called to the fact that the term "equivalent" in this connection refers to quantity only. It does not affect the question of the specific Master's degree (Arts or Science), to which a given student's work would lead.

[2] In exceptional cases the Deans, upon the recommendation of the departments concerned, may accept an additional major in lieu of the dissertation.

[3] In case the candidate did not obtain his Bachelor's degree at the University of Chicago, he will present to the Examiner on blanks furnished for the purpose a detailed statement of his undergraduate work. The Examiner cannot always report upon these statements during the opening week of the quarter.

c) The presentation of a satisfactory thesis upon a subject which has been approved by the Head of the Department in which the principal part of the candidate's work has been done.

d) A good command of literary expression and such knowledge of subjects considered fundamental as may be prescribed by the several departments.

e) Candidates for the degree of Doctor of Philosophy may not, as a rule, take more than two-thirds of their work in one department, and may not take work which is to count toward the degree in more than three departments.

3. *Thesis.*—Each student is required to prepare a thesis upon some question connected with his principal subject. This production must constitute an actual contribution to knowledge. Its subject must be submitted for approval to the Head of the Department at least twelve months before the date of the final examination. The thesis itself must be submitted to the Head of the Department one month before the date of the final examination.

Before the meeting of the Graduate Faculties at which the degree is to be recommended, a typewritten copy of the thesis, together with a certificate signed by the Head or Acting Head of the Department that the copy, as submitted, is accepted for publication as the candidate's thesis for the Doctor's degree, shall be filed in the office of the Deans of the Graduate Schools. Said copy may not be withdrawn from the office of the Deans of the Graduate Schools until the required one hundred copies are deposited in the Library.

The candidate shall deposit in the office of the Deans of the Graduate Schools a contract in legal form to the effect that he will furnish the General Library with one hundred copies (including two bound in half-roan) which shall fulfil in format, cover, title-page, and stock all the University requirements.

Any one of the following three methods may be followed:

a) A signed statement may be filed in the Graduate Office from a publishing agency approved as to its technical efficiency by the University Press, and also as to its professional responsibility by the department concerned that the thesis has been received and accepted for publication.

The one hundred copies furnished to the General Library must be separate prints. They must contain no other material and must be put in covers (ninety-eight in paper covers and two in half-roan).

b) The candidate may deposit with the Business Office a legal financial guaranty sufficient to enable the University Press to print the required one hundred copies, including the binding of two copies in half-roan. This guaranty shall mature at the expiration of two years from the date of the conferring of the degree; or

c) The candidate may at his own cost secure publication of the thesis in the form prescribed by the University, in which case the degree will be conferred only after the delivery of the required one hundred copies to the General Library.

Additional thesis regulations:

a) Upon recommendation of a department and approval of the Dean of the Faculty immediately concerned, a briefer form of the Doctor's thesis than that received in satisfaction of requirements for the degree may be accepted for publication.

For instance, the alternative form of publication may be an account of the method pursued in the investigation, together with an abstract of the evidence

used and a complete summary of the conclusions reached; or it may be a single chapter, provided the same represents a distinct unit of investigation.

b) Five typewritten copies of the complete thesis are required for deposit in the library in addition to the printed copies.

c) In case the course provided for in (*a*) is to be adopted, arrangements for the same are made in the Dean's office before the expiration of the term fixed for publication.

d) Clauses (*a*)–(*c*) are held to modify other rules governing publication of theses in the one detail of providing for acceptance of a printed abbreviation in place of the entire material.

4. *Final examination.*—After admission to candidacy the student may present himself for examination in his secondary subject or subjects as soon as he has fulfilled the requirements of the department or departments concerned. He may present himself for the examination in his principal subject, or in both principal and secondary subjects if the examination in the latter has not been taken in advance (1) as soon as he has fulfilled the requirements of the department or departments concerned, and (2) after he has made satisfactory arrangements as regards his thesis. The examination will be conducted by a committee consisting of the members of the principal department concerned, an appointed representative of the secondary department, or a representative of each of them if there are two, of any other members of the secondary department who may choose to attend, and a member of some other department appointed by the Deans of the Graduate Schools.

If the examinations in the secondary subjects are separated, they may not be held in the same quarter, or within two months of each other.

The candidate is required to prepare a typewritten or printed brief of his work, including an analysis of the thesis, and to file six copies of the same with his Dean for distribution to the committee one week before the time set for the examination. In the case of the examination in the secondary department, the statement should include the work in this department, and the statement for the final examination should include the work of both departments.[1]

5. *Non-resident work.*—After being admitted, the student may be allowed to substitute non-resident work for resident work to a limited extent, under conditions to be arranged in consultation with the Dean and the heads of the departments concerned.

6. *Work done in other universities.*—Graduate work done in another university will be accepted as equivalent to resident work in the University of Chicago, provided the institution in which the work was done is of high standing, and sufficient evidence is furnished that the particular work was satisfactorily performed. Graduate work done in other institutions cannot reduce the residence requirement at the University of Chicago to a period less than one year.[2]

[1] The degree of *Doctor of Philosophy* is given, not on the basis of the completion of a certain amount of time spent upon a specified program, but as the recognition and mark of high attainments and ability in the candidate's chosen province, shown first by the production of a thesis evincing the power of independent investigation and forming an actual contribution to existing knowledge; and secondly, by the passing of examinations covering the general field of the candidate's subjects, with more minuteness in the case of the principal subject, with less minuteness in the case of the secondary subject or subjects.

[2] In order to avoid misunderstandings, candidates for higher degrees should consult with their Deans concerning all technical requirements for such degrees, before application is made for admission to candidacy. In all cases candidates should consult early with the heads of the departments within which their major and minor subjects are taken.

XVII. THE DEPARTMENT OF MATHEMATICS

OFFICERS OF INSTRUCTION

Eliakim Hastings Moore, Ph.D., LL.D., Sc.D., Math.D., Professor and Head of the Department of Mathematics.

Oskar Bolza, Ph.D., Non-Resident Professor of Mathematics (Freiburg i. B).

Herbert Ellsworth Slaught, Ph.D., Professor of Mathematics.

George William Myers, Ph.D., Professor of the Teaching of Mathematics and Astronomy, the School of Education.

Leonard Eugene Dickson, Ph.D., Professor of Mathematics.

Gilbert Ames Bliss, Ph.D., Professor of Mathematics.

Ernest Julius Wilczynski, Ph.D., Professor of Mathematics.

Jacob William Albert Young, Ph.D., Associate Professor of the Pedagogy of Mathematics.

William Hoover, Ph.D., Non-Resident University Extension Assistant Professor of Mathematics (Athens, Ohio).

Arthur Constant Lunn, Ph.D., Assistant Professor of Applied Mathematics.

David Raymond Curtiss, M.A., Ph.D., Professor of Mathematics, Northwestern University (Summer, 1914).

Charles Napoleon Moore, Sc.M., Ph.D., Assistant Professor of Mathematics, University of Cincinnati (Summer, 1914).

FELLOWS, 1914–15

Allen Fuller Carpenter, A.B.
William Leroy Hart, S.B.
Olive Clio Hazlett, A.B.
Alfred Lewis Nelson, A.B.
Chester Henry Yeaton, A.M.

GENERAL STATEMENT

The regular Junior College courses are courses 1, 2, 3, 6, and 15.

Students who expect to specialize in Mathematics, Astronomy, or Physics should confer with the instructors in Mathematics in planning their courses. They should take courses 1, 2, 3, 18, 19, and 20. It is possible, however, for students of exceptional ability in Mathematics to pass from course 2 to course 18, if course 3 is taken at the same time as course 18. Students who desire to have at least a glimpse beyond the elements of mathematics should elect courses 3 and 15.

The following courses introductory to the Higher Mathematics are intended both (1) for students making Mathematics their principal subject, and (2) for those making Mathematics their secondary subject, in particular for students of Astronomy and Physics: (A) †Differential and integral calculus with applications (3Mj.); (B) †Solid analytics; selected topics in geometry; theory of equations; determinants and elementary invariants; (C) †Analytic mechanics (2Mj.); vector analysis; celestial mechanics (2Mj.); theory of the potential; (D) †Advanced calculus, †differential equations, †theory of definite integrals, elliptic integrals, Fourier series and Bessel functions, elements of the theory of functions; (E) Synthetic projective geometry; analytic projective geometry; differential metric

geometry; differential projective geometry; (F) Theory of numbers; theory of invariants; selected chapters of algebra; theory of substitutions with applications to algebraic equations; quaternions.

Groups (A)–(F) indicate six sequences of courses running through the usual academic year from October to June. These sequences vary slightly from year to year; the courses marked (†) are given annually, and the other courses usually once in two years.

The undergraduate student who wishes to specialize in Mathematics should take courses of group (A) as Junior College electives, of (B) in his first Senior College year, and of (C) and (D) in his second Senior College year.

The courses of groups (A)–(F) and the special courses in the Higher Mathematics are intended to give the graduate student a comprehensive view of modern mathematics, to develop him to scientific maturity, and to enable him to follow, without further guidance, the scientific movement of the day in mathematics, and, if possible, to take an active part in it by creative research. The special and research courses vary from year to year. They may be classified, in general, as relating to (*a*) Algebra and Arithmetic; (*b*) Analysis; (*c*) Geometry; (*d*) Mechanics and Applied Mathematics; and (*e*) the Foundations and Interrelations of the Mathematical Disciplines as purely abstract deductive systems. Attention is called to courses of type (*d*) offered by the Departments of Astronomy and Physics.

The proper arrangement of courses is a matter of extreme importance; the best arrangement for any student depends on his previous mathematical studies, and should be determined by conference with some member of the Department.

The courses of the Summer Quarter are designed to meet the needs of those college men and others wishing to study Advanced Mathematics, who are able to spend only the summer in residence. The courses of a series of four summer quarters are arranged so as to give a wide view of modern mathematics.

Scholarship examinations.—The competitive examinations for the Senior College Scholarship and for the Graduate Scholarship in Mathematics are held each Spring Quarter at times and places announced in the *Weekly Calendar*. Prospective candidates should confer with the Departmental Examiner in Mathematics. Files of papers set at previous Scholarship examinations are accessible in the Departmental Library. Candidates for the Senior College Scholarship will be examined on courses 1, 2, and 3; those for the Graduate Scholarship on courses 18, 19, 20, 31, 32, 47, 48, and 49.

Models.—A collection of Brill's models: plaster and thread models of quadric surfaces, plaster models of cubic and Kummer's quartic surfaces, models of cyclides and surfaces of constant positive and negative curvature, and thread models of three-dimensional projections of four-dimensional regular bodies.

MATHEMATICAL CLUBS

The Departmental Club meets regularly for the review of memoirs and books, and for the presentation of results of research. The club is conducted by the members of the faculties of Mathematics and Mathematical Astronomy. Graduate students of the departments are expected to attend and otherwise to participate in the meetings of the club.

The Junior Mathematical Club, with fortnightly meetings, is conducted by the graduate students of the departments of Mathematics and of Astronomy and Astrophysics.

HIGHER DEGREES

Master's degree.—Candidates for the Master's degree in Mathematics are expected to offer for examination eight approved courses of groups (B)–(F), including the elements of the theory of functions, and to present a satisfactory thesis on an assigned topic closely related to the subject of one of the courses.

Degree of Doctor of Philosophy.—Candidates for the Doctor's degree with Mathematics as secondary subject are expected to offer for examination courses 18, 19, 20, and six approved courses in advance of course 20.

Candidates for the Doctor's degree with Mathematics as principal subject are expected (1) to offer for examination the subjects covered by fifteen majors of initial courses of groups (B)–(F), and by a considerable body of special courses, in each case presumably most closely related to the subject of the doctoral dissertation, and (2) to present a dissertation, in finished form, embodying valuable results of mathematical inquiry. The subject of the dissertation may be a topic of pure or applied mathematics or of the history, philosophy, or pedagogy of mathematics.

PREPARATION FOR TEACHING

Courses in the history and the teaching of Elementary Mathematics—Arithmetic, Algebra, Geometry, Trigonometry, Analytic Geometry, Calculus, Mechanics—are offered by this Department and the School of Education. These courses embody the conviction that elementary students need to have their mathematics made, not easier, but more perfectly intelligible and attractive. To this end it is believed that teachers should more generally appreciate and utilize in instruction the unity of mathematics, as made up of various closely interrelated parts, and the character of mathematics, as an ideal science developed by abstraction from various more concrete domains.

A) *Secondary-school positions.*—Students who expect to teach mathematics as a major subject in secondary schools should complete at least the following courses in their undergraduate career: (1) Courses in pure mathematics: Trigonometry, College Algebra, Plane Analytic Geometry, Differential and Integral Calculus and Applications of Calculus, Theory of Equations, and the Synoptic course; (2) Courses in applied mathematics: Descriptive Astronomy, Mechanics, and General Physics; (3) The two courses, Principles of Education and Methods of Education, which may be taken either in the Junior College or in the Senior College; (4) Practice teaching in mathematics in the University High School, for which the above courses in education are prerequisite; (5) A course in the Teaching of Secondary Mathematics and a course in the History of Secondary Mathematics.

B) *Minor collegiate positions.*—Those who look forward to teaching mathematics in normal schools and small colleges should as undergraduates complete at least the following courses: (1) The general courses in education and those in the history and teaching of mathematics mentioned in (3) and (5) above; (2) The content courses specified in (1) and (2) above, together with Advanced Calculus (3 majors).

Candidates for these positions should take at least one year of graduate work leading to the Master's degree in Mathematics and during this year should visit some of the college courses in Mathematics with the purpose of observing methods of teaching. It is the intention of the Department to offer such candidates opportunity, as far as possible, to act as assistants in connection with the collegiate classes, in order that they may gain experience through both observation and practice.

C) *University positions.*—Candidates for university positions should qualify for the Doctor's degree. Courses in the history of mathematics and in the principles and practice of education are strongly recommended.

COURSES OF INSTRUCTION

JUNIOR COLLEGE COURSES

0. Solid Geometry.—An elementary course based upon entrance Algebra and Plane Geometry. Mj. Autumn, Mr. ———.

Note.—Students from accredited preparatory schools may present themselves for examination in this subject *at the University* for college credit.

1. Plane Trigonometry.—Mj. Summer, Professor Slaught; Autumn, 2 sections, Associate Professors Laves and Young; Winter, Professor Slaught; Spring, Associate Professor Young.

2. College Algebra.—Prerequisite: course 1. Mj. Summer, Assistant Professor C. N. Moore; Autumn, Mr. ———; Winter, Professor Wilczynski; Spring, Mr. ———.

3. Analytic Geometry.—Elements of plane analytics, including the geometry of the conic sections, with an introduction to solid analytics. Prerequisite: courses 1 and 2. Mj. Summer, Professor Bliss; Autumn, Professor Wilczynski; Winter, Associate Professor Young; Spring, Professor Slaught.

6. College Geometry.—A collegiate sequel to elementary geometry, analogous to college algebra as a sequel to elementary algebra. The course will include systematic study of methods of attack of geometric problems, with applications to various fields including modern geometry of the triangle and geometric conics. Prerequisite: entrance plane geometry. Mj. Summer, Associate Professor Young.

15. Introductory Calculus.—The elementary fundamental principles, methods, and formulas of differential and integral calculus will be carefully studied in connection with simple problems of geometry and the physical sciences. This course is intended primarily for those who do not wish to take the longer course in Calculus (courses 18, 19, and 20). Prerequisite: courses 1 and 2. Mj. Spring, Associate Professor Young.

SENIOR COLLEGE COURSES

18, 19. Calculus I, II.—A development of the three fundamental notions of the Calculus: the derivative, the anti-derivative, the definite integral, with especial emphasis on their geometrical interpretations and their relations to problems in geometry, mechanics, and physics. Prerequisite: courses 1, 2, and 3. Two consecutive majors. Autumn and Winter, Assistant Professor Lunn; Winter and Spring, Professor Slaught.

18. Calculus I: Differential Calculus.—A graphic study of rational algebraic functions and of certain simple irrational transcendental functions, yielding material for a geometric introduction to the fundamental notions and processes of the Calculus. Prerequisite: courses 1, 2, and 3. Mj. Summer, Professor Curtiss.

19. Calculus II: Integral Calculus.—A course aimed at a comprehension of the nature of integration and of its applications to geometry and physics; solution of numerous problems; use of table of integrals. Prerequisite: course 18. Mj. Summer, Assistant Professor C. N. Moore.

20. Applications of the Calculus.—Partial differentiation and multiple integrals. Elements of the theory of Differential Equations and applications of the Calculus to Mechanics. Introduction to Differential Geometry in the plane and in space. Prerequisite: courses 18 and 19. Mj. Spring, ASSISTANT PROFESSOR LUNN. [Not given in 1915.]

25. Graphical Methods in Algebra.—The cross-section paper as a mathematical instrument for the graphical study of the notion of functionality. M. PROFESSOR MOORE. [Not given in 1914–15.]

26. Graphical Analysis.—A brief study by graphical methods of the fundamental principles of Differential and Integral Calculus, with illustrations also of the theory of equations. This course is a desirable supplement to course 18. Mj. ASSISTANT PROFESSOR LUNN. [Not given in 1914–15.]

27. Units and Dimensions.—The theory of units and dimensions as applied to the measurement of concrete magnitudes and the mathematical transcription of physical experiments. Numerical computations and the reduction of observations. Prerequisite: Calculus and General Physics. ½Mj. Autumn, ASSISTANT PROFESSOR LUNN. [Not given in 1914–15.]

29, 30. Selected Topics in Geometry, I, II.—The fundamental notions of projective geometry treated both analytically and synthetically. The method of abbreviated notation and homogeneous co-ordinates. Theory of determinants, and their application to the geometry of two and three dimensions. Projective and dualistic transformations, and the simpler Cremona transformations. Notions of group and invariant. Prerequisite: courses 1, 2, 3, 18, 19. Two consecutive majors. Autumn and Winter, ASSOCIATE PROFESSOR WILCZYNSKI.

31. Solid Analytics.—This course may be taken simultaneously with course 18; it is an advisable antecedent of course 19. Prerequisite: courses 3 and 18. Mj. Winter, PROFESSOR DICKSON. Shorter course. M. Summer, First Term, PROFESSOR MOORE.

32. Theory of Equations.—Text: Dickson's *Elementary Theory of Equations*, 1914, John Wiley & Sons, New York. Prerequisite: Differential Calculus. Summer, PROFESSOR DICKSON; Spring, PROFESSOR DICKSON.

33. Determinants and Elementary Invariants.—Determinants may be taken as a minor for the first term. Prerequisite: course 32. Mj. Spring. [Not given in 1915.]

34. Limits and Series.—Critical theory of convergence of sequences and series of numbers. Sequences and series of functions; uniformity of convergence. Prerequisite: course 18. Mj. Autumn, ASSOCIATE PROFESSOR YOUNG.

35. The Teaching of Elementary-School Mathematics (School of Education: Mathematics 1).—Mj. Winter, PROFESSOR MYERS.

36. The Teaching of Secondary Mathematics (School of Education: Mathematics 2).—Mj. Spring, PROFESSOR MYERS.

37. Critical Review of Secondary Mathematics.—A brief survey of the subject-matter of Secondary Mathematics from the modern point of view, aiming both to organize the theory of the whole scientifically and to gather the products of this work for use in teaching. Primarily for teachers, actual and prospective, but open also to others. Mj. Summer, ASSOCIATE PROFESSOR YOUNG.

38. Synoptic Course in Advanced Mathematics.—A general historical and logical survey of a considerable portion of pure and applied mathematics. Prerequisite: courses 1, 2, and 3. Mj. PROFESSOR WILCZYNSKI. [Not given in 1914–15.]

39. History of Mathematics (School of Education: Mathematics 5).—Mj. Winter, PROFESSOR MYERS.

46. Advanced Calculus.—Selected topics in the Differential and Integral Calculus requiring more extensive and theoretical treatment than is given in courses 18 and 19: for example, development of the formulas for successive

differentiation and the differentiation of implicit functions, Taylor's formula with applications, transformation of variables in differential equations and multiple integrals, line integrals and partial integration of multiple integrals. Prerequisite: courses 18 and 19. Mj. Autumn, PROFESSOR BLISS.

47. Differential Equations.—A study of the more common types of ordinary differential equations, especially those of the first and second orders, with emphasis on geometrical interpretations and applications to geometry, elementary mechanics, and physics. Prerequisite: courses 18, 19, and preferably 20. Mj. PROFESSOR SLAUGHT. [Not given in 1914–15.]

48. Elliptic Integrals.—A systematic development of the theory of indefinite integration, leading to elliptic integrals and the elements of elliptic functions, with attention to problems and applications. This course includes also an introduction to Fourier series. Prerequisite: courses 18, 19, 20, and preferably 46 or 47. Mj. Summer, PROFESSOR SLAUGHT. Mj. Winter, PROFESSOR BLISS.

49. Theory of Definite Integrals.—A course treating of the properties and methods of computing definite integrals, including a study of methods of approximation, improper definite integrals, Eulerian integrals, multiple integrals, with many problems and applications. Prerequisite: course 47. Mj. Spring, PROFESSOR BLISS.

50. Fourier Series and Bessel Functions.— (*a*) A study of the properties of Bessel functions in connection with the solution of a variety of physical problems where they occur directly. (*b*) Trigonometric and Bessel series as solutions of partial differential equations. Byerly's "Fourier Series." Mj. Spring, ASSISTANT PROFESSOR LUNN. [Not given in 1915.]

GRADUATE COURSES

NOTE.—**Students should register for graduate courses only after consultation with instructors.**

65A, B, C, D. Reading and Research in Pure Mathematics.—When in the judgment of the Department it is advisable that students undertake definite mathematical reading and research not closely connected with any current lecture course or seminar, this work will be directed by PROFESSOR MOORE, PROFESSOR DICKSON, PROFESSOR BLISS, OR PROFESSOR WILCZYNSKI. Mj. or DMj. Each quarter.

66A, B, C. Reading and Research in Applied Mathematics.—Advisable reading and research will be directed by PROFESSOR MOORE, PROFESSOR MYERS, OR ASSISTANT PROFESSOR LUNN. Mj. or DMj. Each quarter.

71. Theory of Numbers.—Introductory course. Theory of congruences, with an outlook on the theories of quadratic forms and of algebraic numbers. Mj. Winter, PROFESSOR DICKSON.

74. Theory of Algebraic Numbers.—In particular, Hensel's exhibition of analogies with Weierstrass' theory of functions. Prerequisite: course 71. Mj. Spring, PROFESSOR MOORE.

81. Substitution Groups and Algebraic Equations.—An introduction to the theory of groups of substitutions, with application to the Galois theory of algebraic equations. Mj. PROFESSOR DICKSON. [Not given in 1914–15.]

82. Finite Groups.—Elements of the theory of abstract groups; selected topics on substitution groups, rotation groups, and congruence groups. Applications to various topics of elementary mathematics. Mj. Spring, PROFESSOR DICKSON.

83. Finite Collineation-Groups.—General theory of reducibility of matrices and of linear groups. Complete enumeration of collineation-groups in a given number of variables: the methods of Klein, Gordan, Jordan, Valentiner, and Blichfeldt, with special reference to the ternary and quaternary groups. Examples of advances made in abstract group theory and in permutation-groups by the study of collineation-groups; theorems by Frobenius and Burnside. Prerequisite: a knowledge of the elements of determinants and group theory. Mj. [Not given in 1914–15.]

84. Continuous Groups.—An illumination of the fundamental concepts and theorems of the Lie theory in connection with various classes of problems of geometry. PROFESSOR DICKSON. [Not given in 1914–15.]

91. Introduction to Higher Algebra.—Properties of matrices, invariant factors and elementary divisors; algebraic theory of a single quadratic or bilinear form; theory of pairs of quadratic or bilinear forms. Geometrical applications. Based largely upon Bôcher's *Introduction to Higher Algebra.* Mj. PROFESSOR DICKSON. [Not given in 1914–15.]

93. Theory of Algebraic Invariants.—A first introduction to the non-symbolic theory of invariants of binary forms, followed by an explanation of the symbolic notation, with practice in its use. A lecture course, with a problem day each week. Mj. PROFESSOR DICKSON. [Not given in 1914–15.]

94. Topics of the Theory of Invariants.—An introduction to the algebraic and number-theoretic invariants, with attention to their geometrical applications. Text: Dickson's *Certain Aspects of a General Theory of Invariants*, 1914, in the Madison Colloquium, published by the American Mathematical Society, New York. M. Summer, Second Term, PROFESSOR DICKSON.

96. Quadratic Forms.—The theory of Weierstrass, Kronecker, and Frobenius, with extension to a general domain of rationality. Mj. PROFESSOR DICKSON. [Not given in 1914–15.]

98. Linear Algebras.—An introduction to the theory of hypercomplex numbers, with attention to quaternions, the relations of the theory to matrices, bilinear forms, and groups. Text: Dickson's *Linear Algebras*, 1914, Cambridge Tracts on Mathematics and Mathematical Physics. M. Summer, First Term, PROFESSOR DICKSON.

101. Theory of Functions of a Real Variable.—An elementary course, including a summary view of the linear continuum and the theory of point-sets. Mj. Autumn, PROFESSOR MOORE.

102. Fundamental Existence Theorems in Analysis.—A study of the existence theorems for implicit functions, ordinary and partial differential equations, and their applications in Analysis. Mj. Autumn, PROFESSOR BLISS. [Not given in 1914–15.]

104, 105. Calculus of Variations, I, II.—Examples illustrating the various types of problems. The differential equations of a curve which minimizes a definite integral in a space of two or more dimensions. Other properties of a minimizing curve as deduced by Legendre, Weierstrass, and Jacobi for the case of the plane. Conditions which insure the existence of a minimum. Isoperimetric problems and the more general problems of Lagrange and Mayer. An introduction to the theory for double integrals. Prerequisite: the elements of the theory of functions of real variables. 2Mjs. Winter and Spring, PROFESSOR BLISS.

106. Partial Differential Equations.—The geometrical theory of equations of the first order. Linear equations. Systems of equations of the first order. Introduction to equations of the second order. Applications to geometry and physics. Mj. PROFESSOR BLISS. [Not given in 1914–15.]

108. Differential Equations from the Standpoint of Lie.—The relations between continuous groups and differential equations. The Picard-Vessiot theory of linear differential equations. Mj. [Not given in 1914–15.]

109. Linear Integral Equations.—An introduction to the theories of Fredholm and of Hilbert-Schmidt with applications to mathematical physics. Prerequisite: Theory of Definite Integrals and a certain general mathematical maturity. Mj. PROFESSOR MOORE. [Not given in 1914–15.]

111, 112. Introduction to General Analysis.—Based on Moore's *Introduction to a Form of General Analysis.* The general analysis in question is the theory of systems of classes of functions, functional operations, etc., involving at least one general variable on a general range. A general variable is a variable entering the theory without direct characterization as to quality or range of variation. A

real- and single-valued function ξ of a general variable p has as especially important particular instances: (I) a real number ξ, the variable p having only one value; (II) an n-partite real number $\xi=(\xi_1, \ldots, \xi_n)$, or point ξ in real space of n dimensions, the variable p having the values $p=1, 2, \ldots, n$; (III) an infinite sequence $\xi=(\xi_1, \xi_2, \ldots, \xi_n, \ldots)$ of real numbers, the variable p having the values $p=1, 2, \ldots, n, \ldots$; (IV) a function ξ or $\xi(p)$ of the variable p on the linear interval $0 \leqq p \leqq 1$ of the real number system. The first part of this introductory course considers certain fundamental closure and dominance properties of classes of functions of a general variable, properties possessed in particular by the class: (I) of all real numbers; (II) of all n-partite real numbers; (III_0) of all numerical sequences converging to zero; (III_1) of all absolutely convergent series of real numbers; (IV) of all continuous functions of p on the interval $0 \leqq p \leqq 1$. The course presupposes a knowledge of the elements of the theory of functions of real variables, and is intended to lead to independent investigations in various chapters of general analysis. For second-year graduate students. 2Mjs. Winter, Spring, PROFESSOR MOORE.

113. Theory of Functions of Infinitely Many Variables.—A survey of the recent work of D. Hilbert, E. Schmidt, and others, with applications to differential and integral equations. Prerequisite: course 48 and a certain general mathematical maturity. Mj. Winter, PROFESSOR MOORE.

114. Differential Equations in General Analysis.—Geometry in a function-space. Determination of functions of a real variable t and a general variable p which satisfy a differential equation with respect to t. Prerequisite: course 112. Mj. Autumn, PROFESSOR MOORE.

115. Integral Equations in General Analysis.—A development of the theory of Fredholm, Hilbert, and others in the sense of General Analysis. Prerequisite: course 112. Synoptic course. M. Summer, First Term, PROFESSOR MOORE.

120. Theory of Functions of a Complex Variable.—An introduction to the theory of Weierstrass. Prerequisite: courses 32 and 49. Mj. Summer, PROFESSOR CURTISS.

121. Theory of Functions of a Complex Variable.—Introduction to the algebra and calculus of complex numbers and their geometric representation; conform representation. The theory of power series and the properties of analytic functions. Introduction to the theory of algebraic functions. Prerequisite: courses 47 and 49. Mj. Autumn, PROFESSOR BLISS.

122. Abelian Integrals.—The analytic character of an algebraic function and its geometrical representation by means of a Riemann surface. Abelian integrals on the Riemann surface, with especial attention to the hyperelliptic case. Abel's theorem. Introduction to the theory of the inversion of Abelian integrals. Prerequisite: course 121. Mj. Winter, ASSOCIATE PROFESSOR BLISS. [Not given in 1914–15.]

123. Elliptic Functions.—Elliptic integrals and the Weierstrassian theory of elliptic functions. Applications of elliptic functions. Mj. [Not given in 1914–15.]

124. Hyperelliptic Functions.—The problem of the inversion of hyperelliptic integrals proposed by Jacobi. Canonical systems of integrals and the associated Θ-functions as introduced by Weierstrass. Hyperelliptic functions and their properties, with applications to the theory of elliptic functions. Prerequisite: course 122. Mj. Spring, PROFESSOR BLISS. [Not given in 1914–15.]

127, 128. Modern Theories of Analytic Differential Equations with Applications to Celestial Mechanics, I, II.—Properties of solution of general system of the nth order as functions of independent variable, of parameters, of initial values of dependent variables. Solutions developed as power series in independent variable, in parameters and initial values of dependent variables, by the Cauchy-Lipschitz process, by the Picard approximation process, by continued variation of parameters. Application to elliptic and hyperelliptic functions and periodic solutions of problem of three bodies. Linear equations with applications to

hypergeometric functions. Linear equations with periodic coefficients. Prerequisite: course 121. Two consecutive majors. Winter and Spring, PROFESSOR MOULTON. [Cf. Astronomy 51, 52.]

131. Synthetic Projective Geometry.—The notion of a projective line, plane, or space, illustrated by the corresponding Euclidean form with adjoined ideal elements at infinity, and by an analytical system of points. Elementary projective forms and their projective relations. The principle of duality. Harmonic properties of projective forms and their application to the theory of conic sections in the plane. The relation of the projective and Euclidean theories. Introduction to the projective geometry of space forms. Mj. Summer, PROFESSOR BLISS. [Not given in 1914–15.]

141. Analytic Projective Geometry.—The co-ordinate system of Analytic Projective Geometry. The principle of duality. The projective theory of conic sections. Introduction to the geometry of space. Mj. PROFESSOR BLISS. [Not given in 1914–15.]

142. Higher Plane Curves.—General properties of algebraic curves. Special study of the curves of the third and fourth order. Prerequisite: course 141. [Not given in 1914–15.]

144. Line Geometry.—The line co-ordinates of Plücker and Klein. Complexes, congruences, and ruled surfaces. Prerequisite: course 31. Mj. [Not given in 1914–15.]

145. Higher Geometry.—A general survey of the principal methods and results of recent geometric research. The various systems of co-ordinates and space elements, the rôle of the group concept, and the cultivation of space intuition by the use of models. Prerequisite: Differential Equations, Projective Geometry, and Solid Analytic Geometry. Mj. PROFESSOR WILCZYNSKI. [Not given in 1914–15.]

151. Metric Differential Geometry.—The application of the calculus to the metric theory of twisted curves and surfaces in space. Prerequisite: course 31. Mj. Summer, PROFESSOR BLISS.

154, 155. Projective Differential Geometry, I, II.—This course gives a brief account of Lie's theory, with applications to the theory of invariants of systems of linear differential equations. The projective differential properties of plane and space curves, of surfaces and congruences, then present themselves as a result of interpreting this invariant theory geometrically. Text: Wilczynski's *Projective Differential Geometry of Curves and Ruled Surfaces.* (B. G. Teubner, Leipzig, 1906.) Prerequisite: An elementary knowledge of differential equations and projective geometry. 2Mjs. Winter and Spring, PROFESSOR WILCZYNSKI. [Not given in 1914–15.]

156. Theory of Plane Curves.—Projective and metric differential and integral properties. Texts: Salmon's *Higher Plane Curves* and Wilczynski's *Projective Differential Geometry of Curves and Ruled Surfaces.* Prerequisite: An elementary knowledge of differential equations and projective geometry. Mj. PROFESSOR WILCZYNSKI. [Not given in 1914–15.]

157. Theory of Ruled Surfaces and Space Curves.—Primarily from the point of view of projective differential geometry. Text: Wilczynski's *Projective Differential Geometry of Curves and Ruled Surfaces.* Prerequisite: course 156. Mj. PROFESSOR WILCZYNSKI. [Not given in 1914–15.]

158. Theory of Surfaces and Congruences, with special emphasis upon the projective differential properties.—Prerequisite: Mathematics 157. Mj. PROFESSOR WILCZYNSKI. [Not given in 1914–15.]

160. Vector Analysis.—The elements of vector algebra, vector differentiation and integration, and the linear vector function; illustrated by typical applications to geometry, mechanics, and physics. Prerequisite: courses 31 and 49. Mj. Autumn, ASSISTANT PROFESSOR LUNN.

162. Theory of Electromagnetism in Vector Analysis Treatment.—Prerequisite: course 161. Mj. Winter, ASSISTANT PROFESSOR LUNN.

163. Theory of Attraction and the Potential.—The potential function of gravitation and electrostatics; Laplace's equation, Green's functions, and harmonic analysis; extensions to cases of heterogeneous media, with sketch of the abstract theory as related to linear differential equations of the second order. Emphasis will be laid on the solutions of illustrative problems. Pierce's *Newtonian Potential Function.* Prerequisite: courses 49 and 160. Mj. Autumn, Assistant Professor Lunn. [Not given in 1914–15.]

166. Hydrodynamics.—Kinematics of continuous media and dynamical theory of typical forms of motion in perfect and viscous fluids, with special emphasis on analytic methods of general use in mathematical physics. Mj. Autumn, Assistant Professor Lunn. [Not given in 1914–15.]

167. Theory of Elasticity.—The geometry of strain in a continuous medium, dynamical relations of stress and strain; detailed study of selected problems in the equilibrium and motion of elastic solids. Prerequisite: Advanced Calculus and Analytic Mechanics. Mj. Assistant Professor Lunn. [Not given in 1914–15.]

170. Average and Probability.—The theory of average and probability for finite and infinite sets of elements; the statistical treatment of observations and the method of least squares; introduction to statistical mechanics, with examples from the theories of molecules and electrons. Prerequisite: Differential Equations. Mj. Assistant Professor Lunn. [Not given in 1914–15.]

171. Statistical Mechanics.—This course deals with the mathematical methods used in the treatment of those physical theories where the magnitudes directly accessible to measurement are conceived as averages of multitudes of elements, and physical laws are interpreted as examples of statistical regularity. A brief preparatory treatment of the notions of statistics, and of the main features of the theory of probability, with some examples in geometry and kinematics, will lead to the main work of the course, in the kinetic theory of gases, the electron theory of metals, and some aspects of the theory of radiation. Prerequisite: thorough knowledge of the Calculus. Mj. Summer, Assistant Professor Lunn. [Not given in 1914–15.]

172. Partial Differential Equations of Mathematical Physics; the Conduction of Heat.—A study of certain typical linear partial differential equations occurring in the analytic representation of physical theories, and of the functional expansions of solutions satisfying given boundary conditions; with special reference to the concrete phenomena and physical analogies from which the abstract theory has been generalized. Prerequisite: courses 49 and 160. Mj. Spring, Assistant Professor Lunn. [Not given in 1914–15.]

178. The Theory of Relativity.—After a brief historical introduction, on the notion of relativity of time and space in its classic or Newtonian form, the course will be devoted to a study of the recent theory initiated by Einstein and Minkowski as a geometry of space and time adapted to the representation of physical laws. Special attention will be given to the discrimination between the logical elements of the theory and the special concrete interpretations that may be used in the formulation of experimental results. Mj. Assistant Professor Lunn. [Not given in 1914–15.]

181. General Seminar.—For the consideration of reports of current research and of literature, especially of a fundamental or critical nature. Professor Moore. [Not given in 1914–15.]

XVIII. THE DEPARTMENT OF ASTRONOMY AND ASTROPHYSICS

OFFICERS OF INSTRUCTION

Edwin Brant Frost, A.M., Sc.D., Professor of Astrophysics, and Director of the Yerkes Observatory.

Sherburne Wesley Burnham, A.M., Emeritus Professor of Practical Astronomy in the Yerkes Observatory.

Edward Emerson Barnard, A.M., Sc.D., LL.D., Professor of Practical Astronomy, and Astronomer in the Yerkes Observatory.

Forest Ray Moulton, Ph.D., Professor of Astronomy.

Kurt Laves, Ph.D., Associate Professor of Astronomy.

John Adelbert Parkhurst, S.M., Assistant Professor of Practical Astronomy at the Yerkes Observatory.

Storrs Barrows Barrett, A.B., Assistant Professor of Astrophysics; Secretary and Librarian of the Yerkes Observatory.

William Duncan MacMillan, Ph.D., Assistant Professor of Astronomy.

Oliver Justin Lee, S.M., Ph.D., Instructor in Practical Astronomy at the Yerkes Observatory.

FELLOWS, 1914–15

John William Campbell, A.M.

Francis Easton Carr, A.B.

Jessie May Short, A.B.

INSTRUCTIONAL WORK

The work of the Department of Astronomy and Astrophysics is divided into two parts: (1) Work at the University, comprising: (*a*) elementary instruction in general Astronomy, both theoretical and practical; (*b*) preliminary training in the principles and methods of work underlying the science of Astrophysics (given in part in the Department of Physics); (*c*) graduate and research work in Celestial Mechanics. (2) Graduate and research work in Practical Astronomy and Astrophysics in the Yerkes Observatory at Lake Geneva.

In the work at the University, given by Professor Moulton, Associate Professor Laves, and Assistant Professor MacMillan, emphasis will be laid on the development of the mathematical principles and methods which form the basis of the physical sciences. In addition to the courses in Descriptive Astronomy, Introduction to Celestial Mechanics, and Analytic Mechanics, courses on Periodic Orbits and in the various other branches of Celestial Mechanics will be given within periods not exceeding three years. The most fundamental subjects will be arranged so as to recur at regular intervals, while other more special topics will vary from time to time. The general object of the instruction will be (1) to give experience and preliminary training in the work of observation and reduction; (2) to furnish the student an adequate mathematical basis for successful work in Celestial Mechanics; (3) to direct research work in Celestial Mechanics.

FACILITIES

For instruction in Practical Astronomy a students' observatory is maintained. It is equipped with a modern Warner & Swasey equatorial telescope of 6½ inches aperture which is provided with a filar micrometer, a 5-inch refractor, a 3-inch Bamberg transit instrument, a Bamberg universal instrument, a Riefler sidereal clock, a chronometer, and various smaller accessories. The laboratory courses offered by the Department of Physics afford excellent preliminary training for the work in Astrophysics.

In the work at the Yerkes Observatory, the advanced student is made familiar with modern methods of research in various branches of Practical Astronomy and Astrophysics. The rapid development of the latter science within the last two decades has been fully recognized in the equipment of the Observatory; the special laboratory facilities make many investigations possible which cannot be carried on where the equipment is less complete. In general, the work in progress during the year 1914–15 will include: Researches in solar physics with the spectroscope, spectroheliograph, and photoheliograph; micrometric observations of double stars, planets, satellites, nebulae, and comets; photographic studies of stellar spectra and determinations of motions in the line of sight; photography of stars, comets, nebulae, etc.; photographic investigations of stellar parallax; research in visual and photographic photometry; special astrophysical researches. The opportunity of taking part in these investigations is deemed of more advantage to the qualified student than set courses of instruction; but regular programs of work, with courses of collateral reading, will be laid out as conditions may require.

ADMISSION TO YERKES OBSERVATORY

The Yerkes Observatory is open only to graduate students who have completed the necessary preliminary studies and have had the requisite experience in practical laboratory and observatory work. Students wishing to work at the Observatory should first consult the Director of the Yerkes Observatory, Williams Bay, Wis., and obtain his approval.

DEGREES

The Master's degree.—Students working for a Master's degree in Astronomy are advised to choose three majors of graduate work in the Department of either Mathematics or Physics and six majors in the Department of Astronomy, from courses numbered 5 to 10, 22, and 23.

The degree of Doctor of Philosophy.—The courses prescribed for the Master's degree together with three other graduate courses will meet the requirement for the Doctor's degree, where Astronomy is the minor subject.

Candidates for the Doctor's degree, with Astronomy as major subject, are expected to make their secondary subject either Mathematics or Physics. Students intending to specialize in the lines of Astrophysics will be required to take the work in Theoretical Physics, Advanced Experimental Physics, Sound and Light, and Physical Manipulation. The courses in Astronomy which will be required depend on the phase of the subject which the candidate elects for his special work, and will be arranged for each candidate during the progress of his

work. Students specializing in Celestial Mechanics are expected to spend six months at the Yerkes Observatory, and those working there in Practical Astronomy and Astrophysics are expected to spend six months at the University.

CLUB

The Departmental Club meets fortnightly for the review of memoirs and books, and for the presentation of results of research. The club is conducted by the members of the faculties of Mathematics and Mathematical Astronomy. Graduate students of Mathematical Astronomy are expected to attend regularly and, so far as possible, to participate actively in the meetings of the club.

SEQUENCE OF EARLY COURSES

Undergraduate students who desire to specialize in Astronomy are recommended to take course 19 and its antecedents in Mathematics, and courses 3, 5, 6, 10, 22, and 23 in Astronomy, as a basis for further work.

COURSES OF INSTRUCTION

AT THE YERKES OBSERVATORY

Advanced students in Astronomy may register for work at the Yerkes Observatory, spending their entire time at Williams Bay (see p. 21). The Observatory will be open throughout the summer. Instruction will be offered by the various members of the staff.

JUNIOR COLLEGE COURSES

1. Descriptive Astronomy (Shorter Course).—An elementary course, dealing with fundamental facts, principles, and methods. Frequent access to the Observatory. Mj. Summer, Professor Moulton; Spring, Professor Moulton and Assistant Professor MacMillan.

2. Spherical Trigonometry with Applications to Astronomy.—Prerequisite: Plane Trigonometry. Mj. Winter, Associate Professor Laves.

3A and 3B. Descriptive Astronomy.—Prerequisite: Plane Trigonometry. A two-quarter course dealing with the fundamental facts and principles of Astronomy. Modern as well as Classical methods and results are brought into full discussion. The observational side of the subject also is emphasized. Mj. Autumn, Professor Moulton; Winter, Assistant Professor MacMillan.

4. Introduction to Surveying (Mathematics 1).—Mj. Spring, Associate Professor Laves.

SENIOR COLLEGE COURSES

5. Analytic Mechanics, I.—An introductory course. Prerequisite: Mathematics 18, 19. Mj. Autumn, Associate Professor Laves.

6. Analytic Mechanics. II.—Prerequisite: Astronomy 5. Mj. Winter, Associate Professor Laves.

7. Spherical and Practical Astronomy.—Time, latitude, and longitude determination. Prerequisite: Astronomy 1 and Mathematics 3. Mj. Spring, Associate Professor Laves.

8. Practical Astronomy, I.—Observations of binary stars and determination of their orbits. Mj. Autumn, Associate Professor Laves. [Not given in 1914–15.]

9. Practical Astronomy, II.—Observations of planets and satellites and determinations of satellite orbits. Mj. Associate Professor Laves. [Not given in 1914–15.]

10. Spectroscopy and Astrophysics (Physics 24).—A non-technical treatment of the growth of Spectroscopy, with applications to solar and stellar phenomena. Mj. Spring, ASSOCIATE PROFESSOR GALE.

20. Analytic Mechanics.—Mj. Summer, ASSOCIATE PROFESSOR LAVES.

GRADUATE COURSES

22. Introduction to Celestial Mechanics, I.—Prerequisite: Astronomy 5. Properties of conic section motion, determination of orbits from three or more observations. Mj. Winter, ASSISTANT PROFESSOR MACMILLAN.

23. Introduction to Celestial Mechanics, II.—Special cases of the problems of three bodies: the Lunar theory geometrically considered; variation of the elements and absolute perturbations. Mj. Spring, ASSISTANT PROFESSOR MACMILLAN.

31-36. Research Courses at the Observatory.—Prerequisites: See "Admission to Yerkes Observatory," p. 21. DMj. Each quarter, PROFESSORS AND INSTRUCTORS resident at Yerkes Observatory.

51, 52. Modern Theories of Analytic Differential Equations with Applications to Celestial Mechanics and Periodic Orbits, I, II.—Prerequisite: Astronomy 50. Properties of the solution of a general system of differential equations of the nth order as functions of the independent variable, of the parameters, of the initial values of the dependent variables. Solutions developed as power series in the independent variable, in the parameters, in the initial values of the dependent variables, by the Cauchy-Lipschitz process, by the Picard approximation process, by continued variation of parameters. Applications to elliptic and hyperelliptic functions and to periodic solutions of the problem of three bodies. Linear equations with applications to hypergeometric functions. Linear equations with periodic coefficients. Winter and Spring, PROFESSOR MOULTON.

60. Periodic Solutions of the Problem of Three Bodies.—Autumn, PROFESSOR MOULTON.

80. The Problem of Three Bodies.—Mj. Summer, PROFESSOR MOULTON.

XIX. THE DEPARTMENT OF PHYSICS

OFFICERS OF INSTRUCTION

ALBERT ABRAHAM MICHELSON, PH.D., SC.D., LL.D., F.R.S., Professor and Head of the Department of Physics.
ROBERT ANDREWS MILLIKAN, PH.D., SC.D., Professor of Physics.
CHARLES RIBORG MANN, PH.D., Associate Professor of Physics.
CARL KINSLEY, A.M., M.E., Associate Professor of Physics.
HENRY GORDON GALE, PH.D., Associate Professor of Physics.
HARVEY BRACE LEMON, PH.D., Instructor in Physics.
WILMER HENRY SOUDER, A.M., Assistant in Physics.
CARL DANFORTH MILLER, S.B., Assistant in Physics.
KARL KETCHNER DARROW, S.B., Assistant in Physics.
LEONARD BENEDICT LOEB, S.B., Assistant in Physics.
CHARLES FREDERICK HAGENOW, A.M., Assistant in Physics.
YOSHIO ISHIDA, S.M., Assistant in Physics.

SUMMER, 1914

EDWIN SHERWOOD BISHOP, Instructor in Physics, University High School.
GEORGE WINCHESTER, Professor of Physics, Washington and Jefferson University, Washington, Pa.
NEWLAND FARNSWORTH SMITH, PH.D., Professor of Physics, Central University of Kentucky.
ALBERT E. HENNINGS, Assistant Professor of Physics, University of Saskatchewan.

FELLOWS, 1914–15

PAUL IRVING PIERSON, A.B.
BENJAMIN E. SHACKELFORD, A.M.
OSCAR WILLIAM SILVEY, A.M.

INSTRUCTIONAL WORK

The instructional work in Physics is directed toward the following ends: (1) The training of original investigators in physics; (2) the training of men competent to fill college and university positions as teachers of physics; (3) the training of teachers of physics for secondary schools; (4) the training of pre-engineering and pre-medical students for later professional work; (5) the training of the general student in scientific methods of work, and in the understanding of the place of physical science in the modern world. From the most elementary to the most advanced courses, the laboratory and the problem method of instruction are emphasized.

FACILITIES

The Ryerson Physical Laboratory has been enlarged and remodeled with especial reference to offering the best facilities for research work. The entire lower floor and basement are given up to private research rooms. A well-equipped shop, with skilled instrument-makers, furnishes opportunity for the construction of special pieces of research apparatus. The equipment has been selected with reference to the needs of research, and includes spectroscopic

instruments of highest power, electrical apparatus for work with alternating and direct currents through all ranges of potential, and appliances for high and for low temperature work, including a liquid-air plant. The library of the Department is well equipped for research purposes. A Physics Club is conducted by the members of the Department, and meets regularly for the discussion of the results of research work done in the Ryerson Laboratory and elsewhere.

DEGREES

All candidates for the S.B. degree who elect their major work in Physics are required to take courses 3, 4, and 5 or 6, and either six majors selected from courses 10, 11, 12, 13, 15, 16, 17, 18, 19, 24, and 25, or three of these and three Senior College courses in one of the following departments: Mathematics, Astronomy, Chemistry, Geology, or Geography.

The Master's degree.—Candidates for the Master's degree in Physics are required to take eight majors in Physics and related subjects, and to present in addition a thesis embodying the results of a laboratory problem. All courses in the Department numbered 10 or above, except course 20, will be counted in satisfaction of this requirement, but at least three majors selected from courses 10, 11, 12, 13, and 15 must be included.

The degree of Doctor of Philosophy.—Candidates for the Doctor's degree with Physics as a minor subject must take courses 3, 4, and 5, and six of the following: 10, 11, 12, 13, 15, 16, 17, 18, 19, 24, 25, 31–36, 51, 52, 56, 57, 58, and 59. When Physics is one of two minor subjects, the courses must be arranged by consultation with the Department.

All candidates for the Doctor's degree with Physics as the major subject must take the following courses: 3, 4, 5, 10, 11, 12, 13, 15, and 25, or their equivalent; three majors selected from courses 16, 17, 18, 37, 38, and 39; courses 31–36, and three additional graduate courses selected by the student. Each candidate must also present a thesis embodying the results of original research in some subject approved by the Department. The time required for the thesis work generally varies from three to six quarters.

PREPARATION FOR TEACHING

Students preparing to teach Physics in secondary schools are expected to have completed courses 3, 4, 5 or 6, 14 or 26, and not less than four of courses 10, 11, 12, 13, 15, 16, 17, 18, 19, 24, and 25. See also courses in Physics in the School of Education.

LABORATORY FEES

There is a laboratory fee of $5 for all major courses involving laboratory work in the Department of Physics.

COURSES OF INSTRUCTION

JUNIOR COLLEGE COURSES

1. Elementary Physics.—A first course in the elements of Physics designed primarily for students who do not present entrance Physics. Mj. Autumn, Mr. Hagenow and Mr. Loeb.

2. Elementary Physics.—A continuation of the preceding course, covering the subjects of electricity, sound, and light. Prerequisite: course 1. Mj. Winter, Mr. Hagenow and Mr. Loeb.

3. Mechanics, Molecular Physics, and Heat.—A general college course in mechanics, molecular physics, and heat, presented mainly from the experimental point of view. Prerequisite: entrance Physics, or course 2. Mj. Summer, 3 sections, PROFESSOR SMITH AND PROFESSOR WINCHESTER; Autumn, 3 sections, DR. LEMON, MR. SOUDER, AND MR. DARROW; Winter, DR. BISHOP; Spring, MR. HAGENOW AND MR. LOEB.

4. Electricity, Sound, and Light.—A general college course in electricity, sound, and light, presented mainly from the experimental point of view, and involving the performance of eighteen laboratory exercises in electricity, four in sound, and six in light. Prerequisite: Physics 3. Mj. Summer, 2 sections, PROFESSOR SMITH AND DR. HENNINGS; Autumn, DR. BISHOP; Winter, 3 sections, DR. LEMON, MR. SOUDER, AND MR. DARROW; Spring, MR. SOUDER.

5. Lecture Demonstration Course.—A course of lectures, demonstrations, and recitations supplementing courses 3 and 4 and completing a year's work in college Physics. Recent discoveries and developments in Physics are given especial attention. 5 hours a week. Prerequisite: Physics 4. Mj. Summer and Spring, DR. LEMON.

6. General Survey of Physical Science.—A lecture demonstration course in which familiar physical phenomena are presented and discussed with reference both to their scientific interpretation and to their relations to modern life. Prerequisite: entrance Physics or course 2. Mj. Spring, ASSOCIATE PROFESSOR MANN. [Not given in 1914–15.]

SENIOR COLLEGE COURSES

10. Elementary Mathematical Physics.—A lecture course on the application of Elementary Calculus to Physics and Chemistry, and practice in the solution of problems. Prerequisite: Physics 3 and 4 and not less than one major of Calculus. Autumn, ASSOCIATE PROFESSOR GALE.

11. Heat and Molecular Physics.—A lecture course for advanced and graduate students, covering the Kinetic Theory, Capillarity, Elementary Thermodynamics, Solution, and Electrolysis. Prerequisite: Physics 4 and Calculus. Mj. Autumn, PROFESSOR MILLIKAN.

12. Light.—A lecture course for advanced students covering the more important sections of geometrical and physical optics. Prerequisite: Physics 4 and Calculus. Mj. Winter, ASSOCIATE PROFESSOR GALE.

13. Electricity and Magnetism.—A course of advanced work in Theoretical Electricity and Magnetism, intended to supplement the work in General Physics or to prepare for graduate work. Prerequisite: Physics 4 and Calculus. M. Summer; Mj. Winter, ASSOCIATE PROFESSOR KINSLEY.

14. The Pedagogy of Physics.—A course designed for teachers of Physics in high schools, consisting of lectures and discussions upon choice of subject-matter and methods of presentation best suited to elementary courses in Physics. Prerequisite: courses 3, 4, and 5, or equivalents. Mj., DMj. Summer, DR. BISHOP.

15. Mechanics and Wave-Motion.—A lecture course on the physical meaning and the mathematical derivation of the fundamental equations of Mechanics and Wave-Motion. Prerequisite: Physics 4 and Calculus. Mj. Spring, ASSOCIATE PROFESSOR GALE.

16. Experimental Physics (Advanced): Molecular Physics and Heat.—A course of advanced laboratory work involving the determination of vapor pressures and densities, coefficients of friction of gases and liquids, molecular electrical conductivities, freezing- and boiling-points, latent and specific heats, high and low temperatures, radioactive constants, etc. Prerequisite: course 4. Mj. Spring, PROFESSOR MILLIKAN AND MR. SOUDER.

17. Experimental Physics (Advanced): Light.—A course of advanced laboratory work in Light, consisting of accurate measurements in diffraction, dispersion, interference, and polarization. Prerequisite: course 4. Mj. Summer, Associate Professor Gale and Dr. Lemon; Autumn, Associate Professor Gale.

18. Experimental Physics (Advanced): Electricity and Magnetism, I.—Laboratory work of the same grade as courses 16 and 17, but consisting of measurements in Electricity and Magnetism. Prerequisite: Physics 4. Mj. Spring, Associate Professor Kinsley.

19. Experimental Physics (Advanced): Electricity and Magnetism, II.—Laboratory work accompanied by lectures consisting of the theory and operation of dynamos, motors, and transformers. Prerequisite: Physics 4. M. Summer; Mj. Winter, Associate Professor Kinsley.

20. Physical Manipulation.—A series of exercises not provided in the regular courses of Experimental Physics, but important to the teacher or advanced student. It consists of the following groups:

Group A. *Shop Work* includes the cutting, filing, drilling, tapping, soldering, and polishing of metal, screw cutting, and elementary lathe work.

Group B. *Glass Work* includes the cutting, grinding, drilling, polishing, and testing of glass.

Group C. *Glass Blowing* includes the simpler processes in glass blowing, such as cutting, bending, and joining of tubes, blowing bulbs, sealing in electrodes, etc.

Group D. *Chemical Processes and Physical Preparations* include the silvering of glass, cleaning and distillation of mercury, preparation of fibers for suspension, and materials useful in experimental work. Mj. [Not given in 1914–15.]

24. Spectroscopy and Astrophysics.—A non-technical treatment of the growth of Spectroscopy, with applications to solar and stellar phenomena. Prerequisite: 9 majors. Mj. Spring, Associate Professor Gale.

25. History of Physical Science.—A continuation of course 9 in Philosophy, History of Science (ancient). A discussion of the origin and evolution of modern physical science in its relation to the growth of civilization. Prerequisite: 18 majors credit in college. Mj. Associate Professor Mann. [Not given in 1914–15.]

26. Teaching of Physical Science.—A review of the history of science teaching in America and abroad, and a discussion of present problems and their solution in special cases. Mj. Dr. Bishop.

28. Photographic Processes.—Lectures and laboratory work on the laws of photographic action. Effects of exposure and development on opacity and density; orthochromatism, plate grain, speed, intensification, reduction, and the applications of these to the photography of exceptional subjects. Prerequisite: Calculus. Mj. Spring, Dr. Lemon.

GRADUATE COURSES

31, 32, 33. Theoretical Physics.—A series of lectures chiefly in Theoretical Physics, Hydrodynamics, Elasticity, Capillarity, Molecular Physics, Thermodynamics, Wave-Motion, Sound, Optical Theories, Electricity, and Magnetism. 4 hours a week. Prerequisite: Physics 10, 11, and 13, and Calculus. Autumn, Winter, and Spring, Professor Michelson.

34, 35, 36. Theoretical Physics.—A series of lecture courses. Alternating with 31, 32, and 33. Prerequisite: same as for 31. 3Mjs. Autumn, Winter, and Spring, Professor Michelson.

37, 38, 39. Experimental Physics.—A course of laboratory work, chiefly devoted to the repetition of classical experiments, such as Determination of the Mechanical Equivalent of Heat; Maxwell's "V"; Hertzian Oscillations; Relative and Absolute Wave-Lengths, etc. 10 hours a week. Prerequisite: Physics 16, 17, and 18. 3Mjs. Autumn, Winter, and Spring, PROFESSORS MICHELSON AND MILLIKAN.

40, 41, 42, 43. Research Course.—This course is intended for graduate students who are prepared to undertake special research. Except in the case of a purely mathematical problem, the entire time is to be devoted to work in the laboratory. DMj. Autumn, Winter, and Spring, PROFESSORS MICHELSON AND MILLIKAN.

48. Spectrometry, I.—Laboratory work in photographing and measuring the spectra of various elements. Use of the concave grating, echelon, and interferometer. Prerequisite: consent of the instructor. Mj. Summer and Winter, ASSOCIATE PROFESSOR GALE.

49. Spectrometry, II.—(Continuation of course 48.) Mj. or DMj. Spring, ASSOCIATE PROFESSOR GALE.

51. Thermodynamics.—Lectures upon the fundamental principles underlying the mechanical theory of heat and the application of these principles to physical and thermochemical problems. Prerequisite: two years of college Physics and Calculus. 5 hours a week. Mj. PROFESSOR MILLIKAN. [Not given in 1914–15.]

52. Electron Theory, I.—A course of graduate lectures, covering the work of the last ten years on the electrical properties of gases, the electron theory, and radioactivity. Prerequisite: same as for 51. 5 hours a week. Mj. Winter, PROFESSOR MILLIKAN.

53. Electron Theory, II.—A continuation of 52, dealing with the application of the electron theory to metallic conduction, to the Seebeck, Peltier, Thomson, and Hall effects, to optical phenomena in magnetic fields, to the subject of electromagnetic mass, etc. 5 hours a week. Mj. Winter, PROFESSOR MILLIKAN. [Not given in 1914–15.]

55. Atomic Theories of Radiation and Their Experimental Basis.—A course of graduate lectures on recent theories of radiation, with especial reference to their relations to the laws of thermodynamics. Prerequisite: Elementary Thermodynamics. Mj. Spring, PROFESSOR MILLIKAN.

56. Electron Theory of Electricity.—Electrical phenomena and their place in the electron theory. The discoveries of Roentgen, Zeeman, Thomson, and Rutherford and the modern theory of electricity. Prerequisite: same as for 51. ASSOCIATE PROFESSOR KINSLEY. [Not given in 1914–15.]

57. The Theory of Alternating Currents.—A discussion of transformers, transmission circuits, and the various types of dynamos and motors. Prerequisite: course 18 or 19 and Calculus. Mj. Spring, ASSOCIATE PROFESSOR KINSLEY.

58. Transient Electrical Phenomena.—Theory and demonstration of current flow before the steady state is reached. Oscillations in power circuits and problems in telephone and telegraph transmission. Prerequisite: course 18 or 19 and Calculus. Mj. Winter and Summer, ASSOCIATE PROFESSOR KINSLEY. [Not given in 1914–15.]

59. Modern Spectroscopy.—A lecture course on the theory and use of spectroscopic apparatus and a discussion of spectroscopic and astrophysical phenomena. Prerequisite: same as for 51. ASSOCIATE PROFESSOR GALE. [Not given in 1914–15.]

60. Light Waves and Their Uses.—A course of graduate lectures on recent developments in physical optics. Prerequisite: same as for 51. PROFESSOR MICHELSON. [Not given in 1914–15.]

61. Physical Optics.—Lectures on the fundamental equations of Theoretical Optics and on recent experimental results. Prerequisite: same as for 51. Mj. Summer, ASSOCIATE PROFESSOR GALE.

62. Relativity.—A graduate lecture course for students of advanced Physics and Mathematics. Mj. ASSISTANT PROFESSOR LUNN. [Not given in 1914–15.]

63. Geometrical Optics.—The methods and principles of Geometrical Optics as applied to the designing of optical instruments and the interpretation of their performance. Theory of the ideal instrument and its approximate realization; aberrations; illumination and diffraction; special properties of particular instruments; characteristics of various types of optical glass. Mj. (or M. First Term), Summer, ASSISTANT PROFESSOR LUNN.

64. Electromagnetic Theory.—(*a*) The main experimental facts of electromagnetism and their generalization so far as covered by the Maxwell theory in its abstract form; special problems concerning steady fields, induction, and electromagnetic waves. M. First Term, Summer. (*b*) The electronic interpretation and extension of the Maxwell theory; electromagnetic mass; theory of radiation and conduction; problems relating to moving bodies. M. Summer, Second Term, ASSISTANT PROFESSOR LUNN.

70. Physics Club.—This organization, consisting of all instructors, graduate and advanced students in the Department, meets on Monday of each week from 4:30 to 6:00 for the discussion of recent research.

XX. THE DEPARTMENT OF CHEMISTRY

OFFICERS OF INSTRUCTION

John Ulric Nef, Ph.D., Professor and Head of the Department of Chemistry.
Julius Stieglitz, Ph.D., Sc.D., Professor of Chemistry and Director of Analytical Chemistry.
Herbert Newby McCoy, Ph.D., Professor of Chemistry.
William Draper Harkins, Ph.D., Associate Professor of Chemistry.
Hermann Irving Schlesinger, Ph.D., Assistant Professor of Chemistry.
Lemuel Charles Raiford, Ph.D., Instructor in Chemistry.
Ethel Mary Terry, Ph.D., Instructor in Chemistry.
John William Edward Glattfeld, Ph.D., Research Instructor in Chemistry.
Oscar Fred Hedenburg, A.B., Research Instructor in Chemistry.
Arthur Budd Carter, Ph.C., Curator.
Agnes Fay Morgan, S.B., S.M., Research Assistant.
Wilby T. Gooch, S.B., Assistant in General Chemistry.
Edmund Charles Humphery, S.B., S.M., Assistant in General Chemistry.
Edwin Daniel Leman, S.B., Assistant in Physical Chemistry.
John Tennyson Myers, S.M., Assistant in Quantitative Analysis.
René de Poyen, Assistant in Organic Chemistry.
Raymond David Mullinix, S.B., Lecture Assistant.

FELLOWS, 1914–15

Augustus Laurence Barker, S.M.
Clyde Coleman, A.M., Loewenthal Fellow.
Ralph Edwin Hall, S.M., Swift Fellow.
Merrill Curtis Hart, S.B.
Lawrence Melvin Henderson, S.M.
Helen Tredway, A.B., A.M.

INSTRUCTIONAL WORK

The Department aims to prepare students (1) to teach in colleges or universities; (2) to teach in secondary schools; (3) to fill positions as technical experts or assistants in chemical industries; (4) to become analysts in commercial and sanitary laboratories. The elementary courses may be taken with advantage by students having none of these ends in view.

Special stress will be placed on thoroughness of preparation and the symmetrical development of the student's knowledge. The object of the courses will be not so much to train specialists as to prepare the student to undertake intelligently all kinds of work of a chemical nature. Those intending to become practical chemists will find a thorough course of purely scientific chemistry the best basis for future specialization in any branch of the subject. Those who incline toward inorganic chemistry will be required to do much physical and a considerable amount of organic work; those proposing to become organic chemists will be required to do work in inorganic chemistry of a more advanced nature than that given in the elementary and analytical courses, and some physical chemistry, etc.

RESEARCH

Students are encouraged to begin research work as soon as their preparation justifies it. Facilities for research in all lines, whether of inorganic, organic, or physical chemistry, are provided. Special opportunities to pursue entirely independent research work will be given to maturer students who have already obtained the Doctor's degree.

DEGREES

The degree of Ph.D.: Chemistry as major subject.—The requirements for the degree of Doctor of Philosophy are:

1. The presentation of a thesis embodying the result of original research in General, Inorganic, Organic, Physico-organic, or Physical Chemistry. This must constitute a real contribution to knowledge, and the work is usually done under the direction of an officer of the Department.

2. Especially thorough and mature knowledge of the branches of Chemistry touched by the thesis, and a sufficient knowledge of other fundamental phases of the science.

The general requirements for all candidates, in advance of General Chemistry, are as follows: courses 4,[1] 6–9, 60 or 61, and two majors selected from courses 10, 11, 13–19, 30–32.

In addition to the above, one of the following specific sets of requirements, arranged according to the thesis subject, must be observed:

General Chemistry and Inorganic Chemistry: courses 35, 50–52, and 63, and one major taken from courses 13–19, 30–37, 64; *Organic Chemistry:* courses 32, 35–37, 50, and one major from 10, 13–19, 51, 52, 63, 64; *Physico-organic Chemistry:* courses 31, 35, 36, 50, and 63, and one major taken from courses 10, 13–19, 51, 52, 63, and 64. *Physical Chemistry:* courses 50, 51, 35, 63, 64, and one major taken from courses 10, 13–19, 30–32, 35–37, 52. In addition to one set of these specific requirements at least six half-majors will be chosen from the special lecture courses 40–45, 54–58, 65–71, 80, 81, 83. The research work will require from four to six quarters.

3. Sufficient work in a minor subject—for instance, if Physics is a minor subject, two years of college Physics, including courses 3, 4, 5, and three of the courses 11, 12, 13, 16, 17, 18, 19, 48, 49, 51, 52, 53, 55 or 56. In addition to the regular minor subject, all candidates are advised to take Mineralogy and Crystallography.

The degree of Doctor of Philosophy: Chemistry the secondary subject.—When Chemistry is a secondary subject, the requirement is determined after conference with the Head of the Department in which the major work is done. Courses 2, 3, 6, 7, and 8, and four other majors in advance of 8, will be required when Chemistry is the only secondary subject; courses 2, 3, 6, 7, and 8, and one other major, when Chemistry is one of two secondary subjects. Elementary Physical Chemistry (60 and 61) or Organic Chemistry, according as the major subject belongs to the Physical or the Biological Group, is recommended.

The Master's degree.—For the Master's degree a dissertation and eight majors of graduate work in Chemistry are required if all the work is in this Department. These majors must be selected from courses in advance of 9, with the approval of

[1] Course 4 may be omitted when advanced work in Organic Chemistry is taken.

the Head of the Department. Courses prerequisite to these must be taken, but cannot be counted in reckoning the eight required majors.

The Bachelor of Science degree: Chemistry as major subject.—

I. For the degree of Bachelor of Science with Chemistry as representing the *nine-major sequence* required for the degree, the following courses will be required: 2 and 3 (or 2S and 3S), 4, 6, 7, 8, 60 or 61, and any two other courses in the Department, excepting course 1. If courses 33 and 34, or 30, 31, and 32, are taken, course 4 is not required.

II. For a *six-major sequence* in Chemistry, the following courses are required: 2 and 3, or (2S and 3S), 4, 6, 7, and 8. Course 60 or 61 may be substituted for 4.

III. For the *nine-major sequences with work in other departments* the following combinations will be accepted: (1) Three majors in college *Physics* (courses 3, 4, and 5 but not courses 1 and 2, in Physics) preceding or accompanying six of the Chemistry courses enumerated in I; (2) One to three majors in *Geology* (courses 2 or 2*a*, 3, 11, 12, 30–35, 40–42) when these courses are *taken after* Chemistry courses 3 (or 3S) and 6; (3) Two majors of *Physiological Chemistry*, provided they are taken *after* Chemistry courses 4 and 6; (4) Two majors in *Domestic Science* (Chemistry of Foods and Dietetics), provided these courses *follow* 4 and 6 in Chemistry; (5) Two majors in *Bacteriology* provided they are taken *after* Chemistry courses 4 and 6.

SPECIAL COURSES NOT LEADING TO A HIGHER DEGREE

Special students.—Special or unclassified students, not candidates for a degree, will be received, but in every case they will be required to give evidence, satisfactory to the instructors, that their previous training has been sufficient to enable them to derive full profit from the courses they propose to take.

Preparation for teaching.—While students who have not taken the work required for the Doctor's or Master's degree are not usually recommended for college or university positions, the Bachelor's degree, with a sufficient amount of work in Chemistry, is at present considered preparation for teaching in secondary schools. In general, the work in Chemistry should include at least courses 1, 2, 3 (or 2S and 3S), 4, 6, 7, 8, 60 or 61, and 80, or their equivalent, as well as work in the College of Education. The prospective teacher in secondary schools should be prepared to teach at least one science besides chemistry.

Preparation for technical positions.—1. Thorough scientific training in all branches of chemistry required for the Doctor's degree forms the best basis for a career as a chemical expert in any branch of chemical industry. With this preparation, the principles and details of technical processes are quickly grasped, advances in industrial processes are intelligently followed, and newly discovered principles are readily applied.

2. Students who have taken from ten to fifteen majors of work in the Department are able to fill satisfactorily positions as assistants in technical and analytical laboratories and, after some practical experience, to advance to positions of independent responsibility. Students should take courses 1 to 10, inclusive, two majors in courses 13–19, and course 60 or 61. If the student's work is primarily in Organic Chemistry, he should take, if possible, two or three courses selected from 30–32 and 35–37; if his work is in Inorganic Chemistry primarily, he should take courses 50–52. Students taking the fuller preparation outlined

are given the preference in answering requests received by the Department; but students with less complete training are also sought by technical firms.

3. The Department gives, with other departments (notably Physics and Mathematics) of the University, and the Department of Manual Training of the University High School, the equivalent of three years of a four years' course in Chemical Engineering. Students are able to take a large part of this work in the purely scientific fundamental branches, while they are candidates for a Bachelor's degree.

The Department does not pledge itself to secure positions for those who have studied in it; but, as a matter of fact, competent students find suitable places quickly, and in the past the demand for chemists has far exceeded the supply.

CHEMICAL SOCIETIES

The Kent Chemical Society is a club of students open to all those who have had six majors of Chemistry. The Society meets biweekly to listen to papers by members and others.

The Chicago Section of the American Chemical Society holds monthly meetings (except in Summer) which the students of the University are welcome to attend. Membership in the Society is open to advanced students.

LABORATORY FEES

There is a laboratory fee of $5 per major for all courses involving laboratory work in the Department of Chemistry.

COURSES OF INSTRUCTION

NOTE.—After course 9, the courses are arranged in groups according to subjects: courses 10–29 include courses in Analytical Chemistry, 30–49 in Organic Chemistry, 50–59 in Inorganic Chemistry, 60–71 in Physical Chemistry; 80–89 are general in nature, and 90–99 are research courses. Nos. 10–19, 30–34, 40–43, 60, 61, and 68–71 are open to, and suitable for, Senior College students.

PRIMARILY FOR THE JUNIOR COLLEGES

1. Elementary General Chemistry: Inorganic, I.—Prerequisite: preparatory Physics. DM. Summer, First Term. Classroom, 6 hours a week; laboratory, 12 hours a week; DR. RAIFORD. Mj. Autumn. Classroom, 3 hours a week; laboratory, 6 hours a week; 2 sections, ASSOCIATE PROFESSOR HARKINS AND DR. RAIFORD.

2. General Chemistry: Inorganic, II.—(Continuation of course 1.) Prerequisite: course 1. DM. Summer, Second Term, DR. RAIFORD; Mj. Winter, ASSOCIATE PROFESSOR HARKINS.

NOTE.—Course 2, Winter Quarter, is a continuation of course 1, but may be entered by those having credit for admission Chemistry.

3. General Chemistry: Inorganic, III.—(Continuation of course 2.) Prerequisite: course 2. Mj. Spring, DR. RAIFORD.

NOTE.—Courses 1, 2, and 3 are consecutive courses. Separate credit is given for each, but students are not advised to take one course only. The aim of these courses is to give a definite idea of the fundamental principles of chemistry, and not to overburden the student with a mass of unconnected facts. The conception of chemical equilibrium and the modern theory of solutions are freely used. The lectures will be experimental to a considerable extent. The courses are designed to meet the wants not only of those who wish to go deeper into chemistry, but of all who wish to study the science as part of a liberal education. The lectures and classroom work of 1, 2, and 3 may be taken by graduate students without the laboratory work or laboratory fee.

2S. General Chemistry: Inorganic.—(First Course.) For students who have had preparatory Chemistry. Prerequisite: preparatory Chemistry and preparatory Physics, one unit each. DM. Summer, First Term. Classroom

6 hours a week; laboratory, 12 hours a week; ASSOCIATE PROFESSOR HARKINS. Mj. Autumn. Classroom, 3 hours a week; laboratory, 6 hours a week; PROFESSOR MCCOY.

3S. General Chemistry: Inorganic.—(Continuation of course 2S.) DM. Summer, Second Term, ASSOCIATE PROFESSOR HARKINS. Mj. Winter, ASSISTANT PROFESSOR SCHLESINGER.

NOTE.—Whenever, in exceptional cases, the preparation of a student in 2S justifies it, qualitative analysis may be substituted for 3S.

4. Elementary Organic Chemistry.—Prerequisite: course 3 or 3S. Mj. Classroom, 3 hours a week; laboratory, 6 hours a week; Autumn, PROFESSOR STIEGLITZ.

PRIMARILY FOR THE SENIOR COLLEGES

6. Qualitative Analysis.—(Introductory Course.) The lectures deal with the chemistry of the analytical reactions, and special attention is given to the development and application of the laws of equilibrium and solutions. This course is, in an important sense, one in advanced General Chemistry. Classroom, 2 hours a week; laboratory, 8 or 16 hours a week. Prerequisite: course 3 or 3S. Mj. Summer, DR. TERRY; Autumn, ASSISTANT PROFESSOR SCHLESINGER; Winter and Spring, DR. TERRY.

NOTE.—Courses 6, 7, and 10 form a continuous course, which may be begun in any quarter. The aim of courses 6, 7, and 10 will be to train the student to do intelligent analytical work, based on a knowledge of the scientific principles of the subject, and to apply and amplify his knowledge of General and Physical Chemistry.

7. Qualitative Analysis.—(Continuation of course 6.) Mj. or DM. Summer, Winter, and Spring, DR. TERRY; Autumn, ASSISTANT PROFESSOR SCHLESINGER.

8. Quantitative Analysis.—(Introductory Course.) Chiefly laboratory work in gravimetric and volumetric analysis. Laboratory, 8 or 16 hours a week; lecture, 1 hour. Prerequisite: course 7. Medical students will be admitted to the course after having taken course 6. Mj. or DM. Summer, PROFESSOR STIEGLITZ; Autumn, DR. ———; Winter, PROFESSOR STIEGLITZ AND MR. ———; Spring, DR. ———.

9. Quantitative Analysis.—(Continuation of course 8.) Mj. or DM. Laboratory, 10 or 20 hours a week. Mj. Summer, PROFESSOR STIEGLITZ; Autumn, ———; Winter, PROFESSOR STIEGLITZ AND MR. ———; Spring, ———.

NOTE.—Courses 8 and 9 form a continuous course which may be begun in any quarter.

PRIMARILY FOR THE GRADUATE SCHOOL

10. Advanced Qualitative Analysis.—Prerequisite: course 7. Mj. or DM. Laboratory, 10 or 20 hours a week. Open to Senior College students. Continuation of courses 6 and 7. Summer, Winter, and Spring, DR. TERRY; Autumn ASSISTANT PROFESSOR SCHLESINGER.

11. Advanced Quantitative Analysis.—(Continuation of courses 8 and 9.) Open to students in the Senior Colleges. Mj. or DM. 10 or 20 hours a week. Winter, PROFESSOR STIEGLITZ.

12. Elementary Spectrum Analysis (Qualitative).—Emission (flame and electric spark) and absorption spectra of inorganic substances. Chiefly laboratory work. ½Mj. Winter, ———.

13–19. Special Methods in Quantitative Analysis.—Chiefly laboratory work. Open to Senior College students.

13. Electrolytic Methods	½Mj. or Mj.
14. Special Mineral Analysis	Mj.
15. Water Analysis	½Mj.
16. Gas Analysis	½Mj.
17. Organic Elementary Analysis	½Mj.
18. Iron and Steel Analysis	½Mj. or Mj.
19. Proximate Food Analysis	½Mj. or Mj.

Prerequisite: course 9. Domestic science and medical students will be admitted to courses 15 and 19 after having taken course 8. Summer, PROFESSOR STIEGLITZ; Autumn, ———; Winter, PROFESSOR STIEGLITZ; Spring, ———.

20. Assaying.—Fire-assay of gold, silver, and lead ores. Prerequisite: course 9. [Not given in 1914–15.]

25. Toxicology.—½Mj. Autumn, PROFESSOR HAINES AND ASSISTANT.

26. Poisons and Their Detection.—A conference and laboratory course. M. Spring, Second Term, PROFESSOR HAINES.

30. Organic Chemistry.—Prerequisite: Qualitative Analysis. Mj. Autumn, PROFESSOR NEF.

31. Organic Chemistry.—(Continuation of course 30.) Mj. Winter, PROFESSOR NEF.

32. Organic Chemistry.—(Continuation of course 31.) M. Spring, First Term, PROFESSOR NEF.

NOTE.—Courses 30, 31, and 32 form a continuous course, covering the compounds of carbon, including the fatty and the aromatic series. The aim of the courses will be to take up thoroughly the simpler compounds, going with great detail into the chemical behavior, the characteristic reactions, and relationships of the different classes of organic compounds, and considering with great care the synthetic methods by which they can be obtained. Richter's or Bernthsen's *Organic Chemistry* is used as a reference book, but recent literature will, in special cases, be considered in detail.

33. General Organic Chemistry.—Fatty and aromatic series. Prerequisite: course 7. Lectures, 5 hours a week. Mj. Summer, DR. GLATTFELD.

34. Elementary Organic Preparations.—Laboratory work, 10 hours a week. This course is arranged to accompany the lectures of course 33. It may be taken without the lectures by students who have had Organic Chemistry. Prerequisite: course 7. M. or Mj. Summer, DR. GLATTFELD.

35. Organic Preparations.—Laboratory work, 10 or 20 hours a week. Prerequisite: courses 7 and 9, Organic Chemistry (may be taken simultaneously with lectures on Organic Chemistry), and a reading knowledge of German. DM. Summer, First and Second Terms, DR. GLATTFELD; Mj. Autumn, Winter, and Spring, PROFESSOR NEF.

36. Organic Preparations.—(Continuation of course 35.) DM. Summer, First and Second Terms, DR. GLATTFELD; Mj. Autumn, Winter, and Spring, PROFESSOR NEF.

37. Organic Preparations.—(Continuation of course 36.) DM. Summer, First and Second Terms, DR. GLATTFELD; Mj. Autumn, Winter, and Spring, PROFESSOR NEF.

40. Special Chapters of Organic Chemistry.—Lectures. Prerequisite: course 32. M. Spring, Second Term, PROFESSOR NEF.

41. The Aromatic Series.—Lectures, 2 hours a week. Prerequisite: Organic Chemistry. ½Mj. Winter, PROFESSOR STIEGLITZ.

42. The Carbohydrates and the Terpenes and Their Derivatives.—½Mj. PROFESSOR STIEGLITZ. [Not given in 1914–15.]

43. Organic Nitrogen Derivatives.—Uric acid series, pyridine, quinone-imides, and phenazine compounds; a discussion of the alkaloids, ptomaines, and organic dye-stuffs. Prerequisite: course 31. ½Mj. PROFESSOR STIEGLITZ. [Not given in 1914–15.]

44. Physical Chemistry Applied to Organic Problems.—Lectures, 2 hours a week. Prerequisite: courses 31 and 60, 61 or 62. ½Mj. PROFESSOR STIEGLITZ. [Not given in 1914–15.]

45. Selected Topics of Organic Chemistry.—Reversibility; tautomerism; stereoisomerism; organic dye-stuffs; application of the electron theory to organic compounds. Prerequisite: Organic Chemistry. ½Mj. PROFESSOR STIEGLITZ. [Not given in 1914–15.]

46. Relations of Physical Properties and the Constitution of Organic Compounds.—½Mj. Summer, DR. RAIFORD.

50. Inorganic Preparations.—Laboratory work, 10 or 20 hours a week; classroom work, 3 hours a week. Prerequisite: course 9, and a reading knowledge of German. Mj. or DM. Summer and Spring, Associate Professor Harkins; Autumn and Winter, Assistant Professor Schlesinger.

51. Inorganic Preparations.—(Continuation of course 50.) Mj. or DM. Same schedule as 50.

52. Inorganic Preparations.—(Continuation of course 51.) Mj. or DM. Same schedule as 50.

54. Selected Topics in Inorganic Chemistry.—Discussions of selected topics in inorganic chemistry such as peroxides and related salts, complex salts, hydrates, molecular compounds, iso- and heteropoly acids, Werner's theory, structural and space isomerism and optical activity in inorganic compounds, etc. Lectures only. ½Mj. Assistant Professor Schlesinger. [Not given in 1914–15.]

55. Advanced General Chemistry.—Discussions bearing chiefly upon the work of courses 50, 51, and 52, and relating to such subjects as temperature measurement, crystal form and habit, isomorphism, solid solution, double salts, thermal analysis, alloys, transition temperatures, absorption, colloids, etc. This course is intended to supplement the work of the courses in inorganic preparations but can be taken independently. Prerequisite, as for course 50. Lectures only. ½Mj. Assistant Professor Schlesinger. [Probably not given in 1914–15.]

56. Special Topics in Inorganic Chemistry.—A study of recent researches in inorganic chemistry, and a discussion of fields still open for investigation. Special topics to be considered during the year 1914–15: free energy and electromotive force in relation to their application in inorganic chemistry. Prerequisite: Chemistry 60 and Calculus. ½Mj. Spring, Associate Professor Harkins.

60. Elementary Physical Chemistry, I.—Lectures, 2 hours a week; laboratory work, 8 hours a week. Lectures on laws of gases, atomic theory, kinetic theory, optical activity, phase rule, and related topics. Laboratory work on the determination of vapor-densities, molecular weights by freezing- and boiling-point methods, degrees of ionization by conductivity method, transference numbers, optical activity, and reaction velocity. Prerequisite: Physics 1 and Chemistry 8. Mj. Spring, Professor McCoy and Mr. Lemon.

61. Elementary Physical Chemistry, II.—Lectures, 2 hours a week; laboratory work, 8 hours a week. Lectures on laws of solution, ionic theory, electro-chemistry, reaction velocity, chemical equilibrium, and related topics. Laboratory work; continuation of course 60. Mj. Spring, Professor McCoy.

62. Elementary Physical Chemistry.—Selected topics from courses 60 and 61. Lectures, 2 hours a week; laboratory work, 8 hours a week. Mj. Summer, Professor McCoy.

63. Physico-chemical Measurements, I.—Laboratory course. Continuation of 61, including a large variety of typical determinations. Prerequisite: Physics 3 and Chemistry 61. Course 65 should accompany or precede this course. Mj. or DM. Summer, Autumn, and Spring, Professor McCoy.

64. Physico-chemical Measurements, II.—Laboratory course. Continuation of course 63. Mj. or DM. Summer, Autumn, and Spring, Professor McCoy.

65 *a*, *b*, *c*, *d*. **Chemical Dynamics.**—Four consecutive, advanced courses based on *Nernst's Theoretical Chemistry*. Prerequisite: courses 60, 61, 63, and Calculus. ½Mj. each quarter. Autumn and Spring, Professor McCoy.

67. Electro-Chemistry.—Prerequisite: course 60 and Mathematics 15. ½Mj. Professor McCoy. [Not given in 1914–15.]

68. Radioactivity and the Nature of Matter.—Lectures. Prerequisite: course 60. ½Mj. Summer, Professor McCoy.

69. Laboratory Course in Radioactivity.—To accompany or follow course 68. ½Mj. or Mj. Professor McCoy.

71. The Atomic Theory.—Prerequisite: course 8. ½Mj. Professor McCoy. [Not given in 1914–15.]

75. Theories of Solutions, I.—½Mj. Associate Professor Harkins. [Not given in 1914–15.]

76. Theories of Solutions, II.—½Mj. Associate Professor Harkins. [Not given in 1914–15.]

82. Club Meetings.—Meetings of the Kent Chemical Society will be held twice a month. They may be attended by anyone interested. The subjects for the meetings will be announced at least one week in advance. Summer, Autumn, Winter, and Spring.

83. The Teaching of Chemistry.—A series of conferences. ½Mj.

85. The Chemistry and Preparation of Medicinal Drugs.—½Mj. Spring, Professor Haines.

90–94. Research Work.—These courses will include from 30 to 40 hours a week of laboratory work, under the special direction of some one of the instructors in the Department. It is expected that research work for a Doctor's thesis will require 4–6 quarters (4–6 DMjs.). Before being admitted to research, a candidate must satisfy the instructors of the Department that his previous training has been sufficient.

90. Research in Organic Chemistry.—Autumn, Winter, and Spring, Professor Nef.

91. Research in Organic and Physico-organic Chemistry.—Summer, Autumn, and Winter, Professor Stieglitz.

92. Research in Physical Chemistry and Radioactivity.—Summer, Autumn, and Spring, Professor McCoy.

93. Research in General and Physical Chemistry.—Summer, Autumn, and Spring, Associate Professor Harkins.

94. Research in Inorganic and Physical Chemistry.—Autumn, Winter, and Spring, Assistant Professor Schlesinger.

95. Independent Research.—Summer, Autumn, Winter, and Spring.

96. Master's Theses in Quantitative Analysis.

97. Master's Theses in Organic Chemistry.—Summer, Dr. Glattfeld; Summer, Autumn, and Spring, Dr. Raiford.

98. Master's Theses in Qualitative Analysis.—Summer, Winter, and Spring, Dr. Terry.

CHEMISTRY COURSES IN THE DEPARTMENT OF GEOLOGY

Geology 41. The Chemistry and Physics of Ore Deposition.—The course will include: (1) the criteria for the genetic classification of ores; (2) individual work on selected subjects or areas, leading to conclusions regarding the genesis of the ores; and (3) a study of the reports of mining engineers for the purpose of acquiring skill and practice in the interpretation of facts. Prerequisite: Geology 40. Autumn, Dr. Brokaw. [Not given in 1914–15.]

Geology 42. Industrial Geology.—A study of the more important industries in which raw materials of mineral origin are prepared for use. The course includes a brief treatment of the metallurgy of the common metals, and a study of the manufacture of coke, cement, clay products, glass, petroleum products, etc. Field trips on Saturdays to plants in and near Chicago are supplemented by detailed reports on each plant. Special problems will be assigned to students interested in any particular phase of the subject. Expenses about $10. Classroom work 3 days a week. Prerequisite: Geology 2, 3, 5, or 12, and a working knowledge of chemistry. Winter, Dr. Brokaw. [Not given in 1914–15.]

CHEMISTRY COURSES IN THE DEPARTMENT OF HOME ECONOMICS

36. Chemistry of Food.—A study of the chemistry of proteins, carbohydrates and fats, with special emphasis upon the composition of such foods as meat, flour, sugar, milk, butter; adulteration of food. The laboratory work is partly quantitative, for the latter the official methods of analysis being used. Senior College. Prerequisite: Organic Chemistry. Laboratory fee, $3. Mj. Autumn, Winter; DM. Summer, Second Term, ASSISTANT PROFESSOR BLUNT.

37. Chemistry of Food (continued).—A continuation of the work in 36. The subject-matter may be adapted to the special needs of the students. Laboratory and lecture. Graduate or Senior College. Prerequisite: course 36 or its equivalent. Laboratory fee, $3. Mj. Winter, ASSISTANT PROFESSOR BLUNT.

38. Chemistry of Nutrition.—The chemistry of the processes of digestion and absorption of food; excretion; food requirements, including discussion of the quantity of protein, ash constituents, etc., desirable under different conditions. Laboratory and lectures. Graduate or Senior College. Prerequisite: Organic Chemistry, Physiology, and one major of Food Chemistry. Laboratory fee, $3. Mj. Winter; M. Summer, First Term, ASSISTANT PROFESSOR BLUNT.

DOCTORS OF PHILOSOPHY OF THE UNIVERSITY OF CHICAGO

MATHEMATICS

1896 John Irwin Hutchinson, Professor of Mathematics, Cornell University.
On the Reduction of Hyperelliptic Functions ($p=2$) to Elliptic Functions by a Transformation of the Second Degree.

Leonard Eugene Dickson, Professor of Mathematics, University of Chicago.
The Analytic Representation of Substitutions on a Power of a Prime Number of Letters with a Discussion of the Linear Group.

1898 Herbert Ellsworth Slaught, Professor of Mathematics, University of Chicago.
The Cross-Ratio Group of 120 Quadratic Cremona Transformations of the Plane.

1899 John Anthony Miller, Professor of Mathematics and Astronomy, Swarthmore College.
Concerning Certain Elliptic Modular Functions of Square Rank.

1900 Gilbert Ames Bliss, Professor of Mathematics, University of Chicago.
The Geodesic Lines on the Anchor Ring.

George Lincoln Brown, Professor of Mathematics, South Dakota Agricultural College.
A Ternary Linear Substitution Group of Order 3,360.

William Gillespie, Professor of Mathematics, Princeton University.
On the Reduction of Hyperelliptic Integrals ($p=3$) to Elliptic Integrals by Transformation of the Second and Third Degree.

Derrick Norman Lehmer, Associate Professor of Mathematics, University of California.
Asymptotic Evaluation of Certain Totient Sums.

John Hector McDonald, Assistant Professor of Mathematics, University of California.
On the System of a Binary Cubic and Quadratic and the Reduction of Hyperelliptic Integrals of Genus Two to Elliptic Integrals by a Transformation of the Fourth Order.

Ernest Brown Skinner, Assistant Professor of Mathematics, University of Wisconsin.
Ternary Monomial Substitution Groups of Finite Order with Determinant ± 0.

1901 William Findlay, Professor of Mathematics, McMaster University.
The Sylow Subgroups of the Symmetric Group.

Thomas Milton Putnam, Associate Professor of Mathematics, University of California.
The Quaternary Linear Homogeneous Group and the Ternary Linear Fractional Group.

1903 Oswald Veblen, Professor of Mathematics, Princeton University.
A System of Axioms for Geometry.

1904 William Henry Bussey, Assistant Professor of Mathematics, University of Minnesota.
Generational Relations for the Abstract Group Simply Isomorphic with the Group LF(2; p^n).

1904 Herbert Edwin Jordan, Assistant Professor of Mathematics, University of Kansas.
Group Characters of Various Linear Groups.

Arthur Whipple Smith, Associate Professor of Mathematics, Colgate University.
Symbolic Treatment of Differential Geometry.

1905 Thomas Emory McKinney, Professor of Mathematics, University of North Dakota.
Concerning a Certain Type of Continued Fractions Depending on a Variable Parameter.

Robert Lee Moore, Instructor in Mathematics, University of Pennsylvania.
Sets of Metrical Hypotheses for Geometry.

1906 William Raymond Longley, Assistant Professor of Mathematics, Yale University.
A Class of Periodic Orbits of an Infinitesimal Body Subject to the Attraction of n Finite Bodies.

Arthur Ranum, Assistant Professor of Mathematics, Cornell University.
The Group of Classes of Congruent Matrices with Application to the Group of Isomorphisms of Any Abelian Group.

Anthony Lispenard Underhill, Assistant Professor of Mathematics, University of Minnesota.
Invariants under Point Transformations in the Calculus of Variations.

Buzz M. Walker, Professor of Mathematics and Director of School of Engineering, Mississippi Agricultural and Mechanical College.
On the Resolution of Higher Singularities of Algebraic Curves into Ordinary Double Points.

1907 George David Birkhoff, Assistant Professor of Mathematics, Harvard University.
Asymptotic Properties of Certain Ordinary Differential Equations, with Applications to Boundary Value and Expansion Problems.

Robert Lacey Börger, Instructor in Mathematics, University of Illinois.
On the Determination of Ternary Linear Groups in the Galois Field of Order p^2.

Louis Ingold, Assistant Professor of Mathematics, University of Missouri.
Vector Interpretation of Symbolic Parameters.

Nels Johann Lennes, Professor of Mathematics, University of Montana.
Curves in Non-metrical Analysis Situs with an Application in the Calculus of Variations.

Frederick William Owens, Instructor in Mathematics, Cornell University.
The Introduction of Ideal Elements and Construction of Projective n-space in Terms of a Planar System of Points.

Norman Richard Wilson, Professor of Mathematics, University of Manitoba.
Isoperimetrical Problems Which Are Reducible to Non-isoperimetrical Problems.

1908 Mary Emily Sinclair, Assistant Professor of Mathematics, Oberlin College.
On a Compound Discontinuous Solution Connected with the Surface of Revolution of Minimum Area.

1909 Thomas Buck, Instructor in Mathematics, University of California.

Arnold Dresden, Assistant Professor of Mathematics, University of Wisconsin.
The Second Derivatives of the External-Integral.

1909 HARRIS FRANKLIN MACNEISH, Instructor in Mathematics, Yale University.
Linear Polars of the k-hedron in n-space.

1910 ANNA JOHNSON PELL, Instructor in Mathematics, Mount Holyoke College.
I. Biorthogonal Systems of Functions. II. Application to the Theory of Integral Equations.

THEOPHIL HENRY HILDEBRANDT, Instructor in Mathematics, University of Michigan.
A Contribution to the Foundations of Fréchet's Calcul Fonctionnel.

EGBERT J. MILES, Instructor in Mathematics, Yale University.
The Absolute Minimum of a Definite Integral in a Special Field.

RICHARD PHILIP BAKER, Assistant Professor of Mathematics, State University of Iowa.
The Problem of the Angle-Bisectors.

WILLIAM HUNT BATES, Assistant Professor of Mathematics, Purdue University.
An Application of Symbolic Methods to the Treatment of Mean Curvatures in Hyper-Space.

ARTHUR DUNN PITCHER, Assistant Professor of Mathematics, Dartmouth College.
The Interrelation of Eight Fundamental Properties of Classes of Functions.

MARION BALLANTYNE WHITE, Assistant Professor of Mathematics, University of Kansas.
The Dependence of the Focal Point on Curvature in Space Problems of the Calculus of Variations.

1911 LLOYD LYNE DINES, Professor of Mathematics, University of Arizona.
The Highest Common Factor of a System of Polynomials, with an Application to Implicit Functions.

THEODORE LINDQUIST, Professor of Mathematics, Lombard College.
Mathematics for Freshman Students of Engineering.

RALPH EUGENE ROOT, Professor of Mathematics, U.S. Naval Academy.
Iterated Limits in General Analysis.

ALBERT HARRIS WILSON, Associate Professor of Mathematics, Haverford College.
The Canonical Types of Nets of Quadratic Forms in the Galois Field of Order p^n.

1912 EDWARD WILSON CHITTENDEN, Instructor in Mathematics, University of Illinois.
Infinite Developments and the Composition Property ($K_{12}B_1$) in General Analysis.

CHARLES ALBERT FISCHER, Instructor in Mathematics, Columbia University.
Some Contributions to the Theory of Functions of Lines.

CHARLES THOMPSON SULLIVAN, Assistant Professor of Mathematics, McGill University.
Properties of Surfaces Whose Asymptotic Lines Belong to Linear Complexes.

1913 MILDRED LEONORA SANDERSON, Instructor in Mathematics, University of Wisconsin, Madison, Wis.
Formal Modular Invariants with an Application to Binary Modular Covariants.

WILLIAM CHARLES KRATHWOHL, Assistant Professor (elect) of Mathematics, Armour Institute.
Modular Invariants of Two Pairs of Cogredient Variables.

1913 Wilson Lee Miser, Instructor in Mathematics, University of Minnesota, Minneapolis, Minn.
On Linear Homogeneous Differential Equations with Elliptic Function Coefficients.

Frank Marion Morrison, Associate Professor of Mathematics, University of Washington, Seattle, Wash.
On the Relation between Some Important Notions of Projective and Metrical Differential Geometry.

Elton James Moulton, Assistant Professor of Mathematics, Northwestern University, Evanston, Ill.
On Figures of Equilibrium of a Rotating Heterogeneous Fluid Body.

MATHEMATICAL ASTRONOMY

1900 Forest Ray Moulton, Professor of Astronomy, University of Chicago.
Periodic Oscillating Satellites.

1903 William Albert Hamilton, Professor of Astronomy, Beloit College.
The True Radii of Convergence for Expansions as Power Series in the Time, in the Case of Parabolic Motion.

1904 Arthur Constant Lunn, Assistant Professor of Applied Mathematics, University of Chicago.
The Differential Equations of Dynamics.

1905 Delonzo Tate Wilson, Assistant Professor of Mathematics, Case School of Applied Science.
Work on Minor Planets.

1906 Frank Loxley Griffin, Professor of Mathematics, Reed Institute, Portland, Ore.
Certain Periodic Orbits of k Finite Bodies Revolving about a Relatively Large Central Mass.

1908 William Duncan MacMillan, Assistant Professor of Astronomy, University of Chicago.
Periodic Orbits about an Oblate Spheroid.

1909 Herbert Earle Buchanan, Professor of Mathematics, University of Tennessee.
Periodic Oscillations of Three Finite Masses about the Langrangian Circular Solutions.

1911 Daniel Buchanan, Assistant Professor of Mathematics, Queen's University, Kingston, Ontario.
A Class of Periodic Solutions of the Problem of Three Bodies, Two of Equal Mass, the Third Moving on a Straight Line.

1913 Lloyd Arthur Heber Warren, Assistant Professor of Mathematics, University of Manitoba, Winnipeg.
A Class of Asymptotic Orbits in the Problem of Three Bodies.

OBSERVATIONAL ASTRONOMY

1913 Oliver Justin Lee, Instructor in Practical Astronomy, Yerkes Observatory, Williams Bay, Wis.
The Spectroscope System of Camelopardalis

Curvin Henry Gingrich, Assistant Professor of Astronomy, Carleton College, Northfield, Minn.
A Determination of the Photographic Magnitudes of Comparison Stars in Certain Hagen Fields.

PHYSICS

1897 Gordon Ferry Hull, Professor of Physics, Dartmouth College.
On the Use of the Interferometer in the Study of Electric Waves.

Isabel Stone, Principal of American School for Girls, Rome, Italy.
On the Electrical Resistance of Thin Films.

1898 Edwin Sheldon Johonnott, Associate Professor of Physics, Rose Polytechnic Institution.
Thickness of the Black Spot in Liquid Films.

1899 Henry Gordon Gale, Associate Professor of Physics, University of Chicago.
On the Relation between Density and Index of Refraction of Air.

1900 Robert Francis Earhart, Professor of Physics, Ohio State University.
The Sparkling Potentials between Plates at Small Distances.

1901 Fritz Reichmann, Practical Physicist, Troy, N.Y.
The Capacities of Air Condensers for Very Small Distances between the Plates.

1902 Frank Baldwin Jewett, Assistant Chief Engineer, Western Electric Co., New York City, N.Y.
A New Method of Determining the Vapor-Density of Metallic Vapors.

1904 Thomas Eaton Doubt, Associate Professor of Physics, Armour Institute of Technology, Chicago, Ill.
The Effect of Intensity upon the Velocity of Light.

Fannie Cornelia Frisbee (Mrs. Frank B. Jewett), New York City, N.Y.
The Effects of Pressure on Magnetic Induction.

Thomas Carlyle Hebb, Professor of Physics, State Normal School, Marquette, Mich.
The Velocity of Sound.

1905 Frederic Lendhall Bishop, Professor of Physics, University of Pittsburgh, Pittsburgh, Pa.
The Thermal Conductivity of Lead.

Glenn Moody Hobbs, Secretary of the American School of Correspondence, Chicago, Ill.
The Relation between P.D. and Spark-Length for Small Values of the Latter.

Carleton John Lynde, Professor of Physics, MacDonald College, Quebec, Can.
The Effect of Pressure on Surface Tension.

1906 William Richard Blair, Director Government Observatory, Mt. Weather, Va.
The Change of Phase Due to the Passage of Electric Waves through Thin Films.

Lawrence Emery Gurney, Professor of Physics, University of Idaho.
The Viscosity of Water at Very Low Rates of Shear.

1907 George Winchester, Professor of Physics, Washington and Jefferson College, Washington, Pa.
Discharge of Electricity from Metals under the Influence of Ultraviolet Light.

Oliver Charles Clifford, Associate Professor of Electrical Engineering, Armour Institute of Technology, Chicago, Ill.
Susceptibility of Copper and Tin and Their Alloys.

1909 Newland Farnsworth Smith, Professor of Physics, Central College, Danville, Ky.
Effect of Tension on Thermal and Electrical Conductivity.

1909 William Ross Ham, Professor of Physics, Pennsylvania State College, State College, Pa.
The Polarization of Primary X-Rays.

Charles Albert Proctor, Assistant Professor of Physics, Dartmouth College, Hanover, N.H.
The Variation of $\frac{e}{m}$ with Speed in the Case of Cathode Rays.

1910 John Mathias Kuehne, Associate Professor of Physics, University of Texas, Austin, Tex.
The Electrostatic Effect of a Changing Magnetic Field.

Louis Begeman, Professor of Physics, Iowa State Teachers College.
The Determination of "E" by the Cloud Method.

Ansel Alphonso Knowlton, Professor of Physics, Utah State University.
Preparation and Testing of Hensler Alloys.

J. Harry Clo, Professor of Physics, Tulane University, New Orleans, La.
The Effect of Temperature upon the Ionization of Gas.

James Remus Wright, Associate Professor of Physics, University of the Philippines, Manila.
Photo-electric Effects of Aluminum as a Function of the Wave-Length of the Incident Light.

1911 Harvey Fletcher, Professor of Physics, Brigham Young University.
A Verification of the Theory of Brownian Movements and a Direct Determination of the Value of Ne for Gaseous Ionization.

Edwin Sherwood Bishop, Instructor in Physics, University High School, University of Chicago.
A Determination of the Minimum Ionizing Kinetic Energy of an Electron in a Gas.

Harold De Forest Arnold, Research Laboratory, Bell Telephone Company, New York.
Limitations Imposed by Slip and Inertia Terms upon Stokes Law for the Motion of Spheres through Liquids.

Harvey Brace Lemon, Instructor in Physics, University of Chicago.
The Influence of Temperature upon the Intensities of the Lines of the Hydrogen Spectrum.

Howard Wilson Moody, Instructor in Physics, Williams College, Williamstown, Mass.
A Determination of the Ratio of the Specific Heats and the Specific Heat at Constant Pressure of Air and Carbon Dioxide.

1913 Edward James Moore, Associate Professor of Physics, Oberlin College, Oberlin, Ohio.
Reaction Effects Produced by the Discharge of Electricity from Points in Gases and the Bearing of These Effects on the Theory of the Small Ion.

Lachlan Gilchrist, Instructor in Physics, University of Toronto.
An Absolute Determination of the Viscosity of Air.

CHEMISTRY

1894 Adolph Bernhard, State Normal School, La Crosse, Wis.
Ueber die Einführung von Acylen in den Benzoylessigather.

Warren Rufus Smith, Professor of Chemistry, Lewis Institute, Chicago, Ill.
On the Addition Products of the Aromatic Isocyanides.

1896 Bernard Conrad Hesse, Consulting Chemist, New York City.
On Malonic Nitrile and Some of Its Derivatives.

1896 Samuel Ellis Swartz, Professor of Chemistry and Physics, Fairmount College, Wichita, Kan.
The Action of Sodium Ethylate on Amide Bromides.

1897 James Bert Garner, Professor of Chemistry, Wabash College, Crawfordsville, Ind.
Condensations with Benzoin by Means of Sodium Ethylate.

Lauder William Jones, Professor of Chemistry, University of Cincinnati.
On Salts of Nitroparaffine and Acylated Derivatives of Hydroxylamine.

1898 Frank Burnett Dains, Professor of Chemistry, University of Kansas, Lawrence, Kan.
On the Isourea Ethers and Other Derivatives of Ureas.

Otto Folin, Hamilton Kuhn Professor of Biological Chemistry, Harvard Medical School, Boston, Mass.
On Urethanes.

Elizabeth Jeffreys, Professor of Chemistry, Pritchett College, Glasgow, Mo.
On Undecylamine and Pentadecylamine and the Preparation of the Higher Amines of the Aliphatic Series.

Herbert Newby McCoy, Professor of Chemistry, University of Chicago.
On the Hydrochlorides of Carbo-phenylimido Derivatives.

1899 John Charles Hessler, Professor of Chemistry, James Millikin University, Decatur, Ill.
On Alkyl Malonic Nitriles and Their Derivatives.

William McPherson, Professor of Chemistry, Ohio State University, Columbus, Ohio.
On the Nature of the Oxyazo Compounds.

James Harvey Ransom, Professor of General Chemistry, Purdue University, Lafayette, Ind.
On the Molecular Rearrangement of o-Aminophenylethyl Carbonate to o-Oxyphenylurethane.

1900 Henry Chalmers Biddle, Associate Professor of Chemistry, University of California.
Ueber Derivate des Isuretins, der Formhydroxamsäure und ihre Beziehungen zur Knallsäure.

1901 Ralph Harper McKee, Professor of Chemistry, University of Maine, Orono, Me.
On the Oxygen Ethers of the Ureas: Methyl- and Ethylisourea.

1902 Solomon Farley Acree, Associate Professor of Chemistry, Johns Hopkins University, Baltimore, Md.
On Sodium Phenyl and the Action of Sodium on Ketones.

Wallace Appleton Beatty, ———.
The Action of Carbon Monoxide on Sodium Alcoholates Alone and in the Presence of Salts of Fatty Acids.

Eugene Paul Schoch, Professor of Chemistry, University of Texas, Austin, Tex.
The Red and the Yellow Mercuric Oxides and the Mercuric Oxychlorides.

Edwin Emery Slosson, Literary Editor of *The Independent*, New York City.
On Acylhalogenamine Derivatives and the Beckmann Rearrangement.

1903 Henry Tabor Upson, Vice-President and Manager of Pease Oil Co., Buffalo, N.Y.
The Molecular Rearrangement of Aminophenylalkyl Carbonates.

1904 MAXWELL ADAMS, Professor of Chemistry, State University, Reno, Nev.
On Some Hydroxylamine Compounds.

RAYMOND FOSS BACON, Acting Director of Industrial Research, University of Pittsburgh, Pittsburgh, Pa.
On the Reactions of Sodium Benzhydrol.

WILLIAM MCAFEE BRUCE, Professor of Chemistry, Arkansas Agricultural College.
On the Oxygen Ethers of Urea.

NELLIE ESTHER GOLDTHWAITE, Assistant Professor of Household Science, University of Illinois, Champaign, Ill.
On Substituted Benzhydrol Derivatives and Bromcyanacetic Ether.

OSWIN W. WILLCOX, Technical Chemist, New York, N.Y.
On the Reactions of Ethyl Chlorsulphonate.

1905 WILLIAM LLOYD EVANS, Professor of Chemistry, Ohio State University, Columbus, Ohio.
On the Behavior of Benzoyl Carbinol toward Alkalies and Oxidizing Agents.

WILLIAM MCCRACKEN, Professor of Natural Sciences, State Normal School, Kalamazoo, Mich.
Studies in Catalysis. V. The Catalysis of Imidoesters.

HERMANN SCHLESINGER, Assistant Professor of Chemistry, University of Chicago.
Studies in Catalysis. VI. The Catalysis of Imidoesters.

1906 ROY HUTCHINSON BROWNLEE, Associate Professor of Industrial Research, University of Pittsburgh, Pittsburgh, Pa.
On Precipitated Sulphur.

CHARLES M. CARSON, Professor of Chemistry, Houghton School of Mines, Houghton, Mich.
On Amorphous Sulphur: Further Study of the Two Forms of Liquid Sulphur as Dynamic Isomers.

HENRY MAX GOETTSCH, Assistant Professor of Technical Chemistry, University of Cincinnati, Cincinnati, Ohio.
The Absorption Coefficients of Uranium Compounds.

WILLIS STOSE HILPERT, Chemist, American Medical Association, Chicago, Ill.
Stereoisomeric Chlorimido Acid Esters.

JAMES WRIGHT LAWRIE, Chief Chemist and Manager for Jobbins & Co., Aurora, Ill.
The Chemistry of the Acetylidene Compounds.

ANDREW FRIDLEY MCLEOD, Instructor in Chemistry, Beloit College, Beloit, Wis.
On Aldol, Pentaerythrose, and the Action of Copper Acetate on the Hexoses.

1907 *EDITH ETHEL BARNARD
The Catalysis of Imidoesters as Affected by the Presence of Non-Electrolytes and Electrolytes.

KATHERINE BLUNT, Assistant Professor of Home Economics, University of Chicago.
The Formation of Amidines.

WILLEY DENIS, Research Assistant, Harvard Medical School, Cambridge, Mass.
On the Behavior of Various Aldehydes, Ketones, and Alcohols toward Oxidizing Agents.

ROBERT ANDERSON HALL, Assistant Professor of Chemistry, University of Minnesota, Minneapolis, Minn.
The Action of Ammonia on Isourea Esters.

* Deceased.

1907 Louis Allen Higley, Professor of Chemistry, Westminster College, Fulton, Mo.
On the Behavior of Sodium and Sodium Alcoholates toward Various Esters.

William Horace Ross, Research Chemist, Bureau of Soils, Department of Agriculture, Washington, D.C.
On the Relation between the Radioactivity and the Composition of Thorium and Uranium Minerals.

Louis A. Test, Associate Professor of Chemistry, Iowa State College, Ames, Ia.
The Rearrangement of o-Amino Phenyl Esters.

1908 George Cromwell Ashman, Professor of Chemistry, Bradley Institute, Peoria, Ill.
Studies in Radioactivity.

1909 Ernest Anderson, Assistant Professor of Chemistry, Massachusetts State Agricultural College, Amherst, Mass.
The Action of Fehling's Solution on *d*-Galactose.

William Weldon Hickman, Professor of Chemistry, Assuit College, Assuit, Egypt.
The Catalysis of Imidoesters.

Winford Lee Lewis, Assistant Professor of Chemistry, Northwestern University, Evanston, Ill.
The Action of Fehling's Solution on Maltose.

Peter Powell Peterson, Instructor in Soil Investigations, University of Wisconsin, Madison, Wis.
Stereoisomerism of Chlorimido-Ketones.

Lemuel Charles Raiford, Instructor in Chemistry, University of Chicago, Chicago, Ill.
Chlorimido Quinones.

Herman Augustus Spoehr, Chemical Plant Physiologist, Carnegie Institution, Tucson, Ariz.
The Behavior of the Ordinary Hexoses toward Hydrogen Peroxide in the Presence of Alkaline Hydroxides as Well as of Various Iron Salts.

1910 Alan W. C. Menzies, Professor of Chemistry, Oberlin College, Oberlin, Ohio.
Studies in Vapor-Pressure.

Emma Perry Carr, Professor of Chemistry, Mount Holyoke College, Mt. Holyoke, Mass.
The Aliphatic Imidoesters.

Elbert Edwin Chandler, Professor of Chemistry, Occidental College, Los Angeles, Cal.
Ionization Constants of the Second Hydrogen Ion of Dibasic Acids.

Ira Harris Derby, Assistant Professor of Chemistry, University of Minnesota, Minneapolis, Minn.
Studies in Catalysis of Imidoesters, IV.

Stewart Joseph Lloyd, Professor of Chemistry and Metallurgy, University of Alabama, University, Ala.
Studies in Radioactivity.

John Colin Moore, Instructor in Chemistry, Lake View High School, Chicago, Ill.
The Action of Water on Acyl Isoureas.

William Cabler Moore, Research Chemist, National Carbon Co., Cleveland, Ohio.
Studies in Organic Amalgams.

1910 Fred Wilbert Upson, Professor of Chemistry, Agricultural College, University of Nebraska, Lincoln, Neb.
On the Action of Normal Barium Hydroxide on d. Glucose and d. Galactose.

1911 Thomas Bruce Freas, Assistant Professor of Chemistry, Columbia University, New York, N.Y.
A Study of Thermostats.

John Foote Norton, Assistant Professor of the Chemistry of Sanitation, Massachusetts Institute of Technology, Boston, Mass.
Simultaneous Reactions in Amidine Formation.

Harlan Leo Trumbull, Instructor in Chemistry, University of Washington, Seattle, Wash.
The Molecular Rearrangement of Acid Chloramides and the Ionization of Their Salts.

Leroy Samuel Weatherby, Professor of Chemistry, University of Southern California, Los Angeles, Cal.
The Salt-Effects of the Nitrates and Sulphonates in the Catalysis of Imidoesters.

Franklin Lorinzo West, Professor of Chemistry, Utah Agricultural College, Provo, Utah.
The Physical and Chemical Properties of Organic Amalgams.

1912 Paul David Potter, Chief Chemist, Sprague, Warner & Co., Chicago, Ill.
The Hydrates of Arsenic Pentoxide.

Charles Herman Viol, Chief Chemist, Standard Chemical Co., Pittsburgh, Pa.
The Chemical Properties and Relative Activities of the Radio-Products of Thorium.

1913 George Oliver Curme, Jr., Research, University of Berlin.
The Thermal Decomposition of the Symmetrical Diaryl-Hydrazines.

John William Edward Glattfeld, Research Instructor, University of Chicago.
The Oxidation of *d*-Glucose in Alkaline Solution by Air as Well as by Hydrogen Peroxide.

Paul Nicholas Leech, Research Chemist, American Medical Association.
The Molecular Rearrangement of Triaryl Methyl Hydroxylamines; a New Interpretation for the Rearrangement of Ketoximes.

Ethel Mary Terry, Instructor in Chemistry, University of Chicago.
The Velocity Coefficient of Saponification of Ethyl Acetate.

1914 Arthur Wesley Martin, Professor of Chemistry and Physics, University of Nanking, Nanking, China.
Studies on Solutions in Anhydrous Formic Acid.

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1917/18
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The University of Chicago

FOUNDED BY JOHN D. ROCKEFELLER

CIRCULAR OF THE DEPARTMENTS OF

MATHEMATICS, ASTRONOMY AND ASTROPHYSICS, PHYSICS CHEMISTRY

1917

UNIVERSITY OF ILLINOIS
JUL 14 1917
Administrative Library

THE UNIVERSITY OF CHICAGO PRESS
CHICAGO, ILLINOIS

CALENDAR FOR THE YEAR 1917–18

1917

June 10	Sunday	Convocation Sunday
June 11	Monday	College Day
June 12	Tuesday	Summer Convocation
June 13	Wednesday	Quarterly Examinations
June 14	Thursday	
June 15	Friday	
June 15	Friday	Spring Quarter ends
June 18	*Monday*	*Summer Quarter begins*
June 18–22		Examinations of the College Entrance Examination Board
July 4	Wednesday	Independence Day: a holiday
July 14	Saturday	Special Examinations for removal of deficiencies (work reported conditioned or incomplete) incurred during the last quarter of residence
July 24	Tuesday	Examinations for First Term of Summer Quarter
July 25	Wednesday	
July 25	Wednesday	First Term of Summer Quarter ends
July 26	Thursday	Second Term of Summer Quarter begins
Aug. 26	Sunday	Convocation Sunday
Aug. 30	Thursday	Examinations for Second Term of Summer Quarter
Aug. 31	Friday	
Aug. 31	Friday	Autumn Convocation Second Term of Summer Quarter ends
Sept. 3–8		Entrance Examinations
Sept. 27–29		Registration for Autumn Quarter
Sept. 29	Saturday	Special Examinations for all students returning for the Autumn Quarter, who incurred deficiencies (work reported conditioned or incomplete) in the last quarter of residence
Oct. 1	*Monday*	*Autumn Quarter begins*
Nov. 29	Thursday	Thanksgiving Day: a holiday
Dec. 16	Sunday	Convocation Sunday
Dec. 18	Tuesday	Winter Convocation
Dec. 19	Wednesday	Quarterly Examinations
Dec. 20	Thursday	
Dec. 21	Friday	
Dec. 21	Friday	Autumn Quarter ends

1918

Jan. 2	*Wednesday*	*Winter Quarter begins*
Jan. 26	Saturday	Special Examinations for removal of deficiencies (work reported conditioned or incomplete) incurred during the last quarter of residence
Feb. 12	Tuesday	Lincoln's Birthday: a holiday
Feb. 22	Friday	Washington's Birthday: a holiday
Mar. 17	Sunday	Convocation Sunday
Mar. 19	Tuesday	Spring Convocation
Mar. 20	Wednesday	Quarterly Examinations
Mar. 21	Thursday	
Mar. 22	Friday	
Mar. 22	Friday	Winter Quarter ends
Mar. 23–31		Quarterly recess
April 1	*Monday*	*Spring Quarter begins*
April 18–19		Annual Conference with Co-operating Schools
April 27	Saturday	Special Examinations for removal of deficiencies (work reported conditioned or incomplete) incurred during the last quarter of residence
May 30	Thursday	Memorial Day: a holiday
June 9	Sunday	Convocation Sunday
June 10	Monday	College Day
June 11	Tuesday	Summer Convocation
June 12	Wednesday	Quarterly Examinations
June 13	Thursday	
June 14	Friday	
June 14	Friday	Spring Quarter ends

OFFICERS OF ADMINISTRATION

Harry Pratt Judson, President of the University, Harper Memorial Library, Room W11.

Ernest DeWitt Burton, Director of the University Libraries, Harper Memorial Library, Room M27.

Walter A. Payne, University Recorder and University Examiner, Cobb Lecture Hall, Room 5A.

David Allan Robertson, Secretary to the President, Harper Memorial Library, Room W13.

James Rowland Angell, Dean of the Faculties of Arts, Literature and Science, Cobb Lecture Hall, Room 6A.

Albion Woodbury Small, Dean of the Graduate School of Arts and Literature, Cobb Lecture Hall, Room 6A.

Rollin D. Salisbury, Dean of the Ogden Graduate School of Science, Cobb Lecture Hall, Room 6A.

Marion Talbot, Dean of Women, Cobb Lecture Hall, Room 14A.

Leon Carroll Marshall, Dean of the Senior Colleges, and Dean of the College of Commerce and Administration, Cobb Lecture Hall, Room 6B.

Robert Morss Lovett, Dean of the Junior Colleges, Cobb Lecture Hall, Room 9A.

Henry Gordon Gale, Dean in the Colleges of Science, Cobb Lecture Hall, Room 7A.

Horatio Hackett Newman, Dean in the Colleges of Science, Cobb Lecture Hall, Room 10A.

Percy Holmes Boynton, James Weber Linn, Ellis Hall; Frank Justus Miller, Elizabeth Wallace, Lexington Hall: Deans in Junior Colleges.

Sophonisba Preston Breckinridge, Assistant Dean of Women, Lexington Hall.

Nathaniel Butler, Director of Co-operation with Secondary Schools, Cobb Lecture Hall, Room 16A.

GENERAL INFORMATION

The organization of the University includes: the Graduate School of Arts and Literature; the Ogden Graduate School of Science; the Colleges (Senior, last two years, and Junior, first two years) of Arts, Literature, and Science; the Divinity School, the Law School, Courses in Medicine, the School of Education, the School of Commerce and Administration.

Faculty and equipment.—The faculty (exclusive of assistants) numbers three hundred and three; the libraries contain 485,847 volumes and 200,000 pamphlets (estimated). The University owns nearly one hundred acres of land in Chicago and has forty buildings.

Location of the University.—The University grounds lie on both sides of the Midway Plaisance between Washington and Jackson parks, six miles south of the center of Chicago. Electric cars, elevated trains, and the Illinois Central suburban service reach all railway stations. Mail and baggage service is provided at the Information Office of the University.

The University year is divided into quarters: the Autumn (October, November, December); the Winter (January, February, March); the Spring (April, May, to the middle of June); the Summer (from the middle of June, July, August). For the year 1917–18 the exact dates for the opening of the four quarters are: Summer Quarter, June 18, 1917; Autumn Quarter, October 1, 1917; Winter Quarter, January 2, 1918; Spring Quarter, April 1, 1918. Students are admitted at the opening of each quarter; graduation exercises are held at the close of each quarter.

The unit of work and of credit is a *major*, i.e., a course of instruction involving four or five recitations or lecture hours per week for a full quarter, or double that number of hours for a term of six weeks. A *minor* is one-half a major. Normal work is three majors per quarter, or nine per year of three quarters.

Degrees.—The University confers in the Graduate Schools the degrees of Doctor of Philosophy and of Master of Arts and of Science; in the Colleges, the degrees of Bachelor of Arts, of Science, and of Philosophy; in the Divinity School, the degrees of Bachelor of Divinity, of Master of Arts, and of Doctor of Philosophy; in the Law School, the degrees of Doctor of Law and of Bachelor of Laws; in the School of Education, the degrees of Bachelor of Arts in Education, of Philosophy in Education, and of Science in Education; in the School of Commerce and Administration, the degree of Bachelor of Philosophy.

Fellowships, scholarships, student service, etc.—By virtue of endowments and special appropriations, fellowships and scholarships and service afford stipends or tuition to a number of able and deserving students. The University also maintains a bureau for securing outside employment.

Guests of the University.—Under certain conditions (see p. 6) Doctors of Philosophy of the University of Chicago, and of other universities, will be welcomed by the President of the University as guests of the University.

FEES FOR MATRICULATION, TUITION, ETC.

A. *Matriculation fee.*—The Matriculation fee is $5.00, and is required of every student on entrance into the University.

B. *Tuition fee.*—1. The tuition fee for new students in the Colleges, the School of Commerce and Administration, and the School of Education, including also unclassified students is:

One major, $25.00.
Two or three majors, $50.00.
Each additional major above three, $20.00.

For those students who have been registered in the above-mentioned groups prior to the Summer Quarter, 1917, the tuition fee will remain as heretofore, $40.00 for two or three majors, $20.00 for a single major, and for each additional major over three, $15.00.

2. *All tuition and laboratory fees are due on or before the first day of each quarter, and are payable without extra fee up to the end of the fifth day of the quarter. All fees are payable to the Cashier*, Press Building, Room 1.

C. *Fines, etc.*—For failure to pay tuition fees within the first five days of the quarter a fee of $5.00 is added to the bill.

D. *Laboratory fee.*—Students in most laboratory courses pay a laboratory fee of $5.00 a major (M. or DMj. courses will be charged in proportion). In the Departments of Home Economics and Household Art, Modeling and Ceramics, and Manual Training, laboratory fees varying from $1.50 to $6.00 are charged for certain courses, depending on the nature of the courses. Ten dollars ($10.00) is the maximum charge for laboratory work in any one department. In addition to the regular laboratory fee, students in Chemistry will procure a coupon ticket, entitling them to $5.00 worth of laboratory material. Students doing laboratory work in the Departments of Zoölogy, Anatomy, Physiology, Botany, Pathology, and Hygiene and Bacteriology are required to purchase a laboratory supply and breakage ticket ($5.00 for a single course and $10.00 for more than one course in this group of departments) at the office of the Cashier, and file the same at the laboratory supply store, Room 10, Botany Building.

E. *A small material fee* is charged in certain courses in Political Economy and Sociology.

F. *Gymnasium locker fee.*—For the use of a locker in the dressing-room of the gymnasium a fee of $1.00 a quarter is charged. A small fee is also charged for the use of the tennis courts.

G. *Graduation fee.*—The general graduation fee, including diploma, is $10.00. The graduation fee for Doctors of Philosophy, including diploma and hood, is $15.00. In the case of students taking the certificate of a two years' course the charge is $5.00.

ROOMS, BOARD, AND GENERAL EXPENSES

There are ten dormitories in the University quadrangles. Two of these are reserved for the students of the Divinity School, and five are for women. A University House is organized in each dormitory; each House has a Head, appointed by the President of the University, and a House Committee, elected by the members; also a House Counselor, selected from the Faculties of the

University by the members of the House. The membership of the House is determined by election, and each House is self-governing under the general control of the University.

The cost of rooms in the dormitories is from $25.00 to $75.00 per quarter of twelve weeks. This includes heat, light, and care. Each hall for women has separate dining-hall and parlors. The cost of table board in these halls is $4.50 per week.

All applications for rooms, or for information concerning rooms and board within or without the quadrangles, should be made to the Cashier.

The table shown below will furnish an estimate of the annual expenses, exclusive of tuition and laboratory fees for thirty-six weeks of a student in the University residing within the quadrangles. It is believed that students who find it necessary to reduce expenses below the lowest of these estimates can do so. By application to the Housing Bureau, rooms outside the quadrangles, furnished, heated, lighted, and cared for, may be obtained at from $25.00 a quarter upward, but there are very few rooms to be had at this price. For $30.00 a quarter a much wider choice is possible. Room and board in private houses are offered from $7.00 per week upward. A cafeteria service is provided at the Men's Commons in Hutchinson Hall, at the Refectory in Ida Noyes Hall, and at the School of Education Lunchroom at a cost ranging from $4.50 a week upward. During the Summer Quarter the University Commons is open to both men and women.

	Lowest	Average	Liberal
Rent and care of room	$ 60.00	$105.00	$225.00
Board	135.00	162.00	225.00
Laundry	15.00	25.00	35.00
Textbooks and stationery	10.00	20.00	50.00
Total	$220.00	$312.00	$535.00

DOCTORS OF PHILOSOPHY AS GUESTS OF THE UNIVERSITY

The President of the University, on recommendation of a Head of a Department, will welcome Doctors of Philosophy of the University of Chicago as well as of other universities as guests of the University, with the privilege of attending seminars and of carrying on research in the laboratories and libraries. There will be no charge except for laboratory supplies and a nominal laboratory fee where laboratory work is done. Arrangements should be made in advance with the President of the University.

FELLOWSHIPS AND SCHOLARSHIPS

The Trustees appropriate annually the amount of twenty-two thousand one hundred and forty dollars ($22,140) for Fellowships in the Graduate Schools of Arts, Literature, and Science. These Fellowships range in value from $120, the tuition fees of a graduate student for three quarters, to $520, that is, $400 in addition to the tuition fees for three quarters. A limited number of Scholarships, covering a part or all of the tuition fees for three quarters, are also awarded annually.

Candidates for these Fellowships and Scholarships should send to the Deans of the Graduate Schools a record of their previous work and distinctions, degrees and past courses of study, with copies of their written or printed work in the field of the department in which application is made. Applications must be received at the Deans' offices *not later than March 1 of each year*, in order to be considered for the following year. Appointments will be made April 1.

Fellows may be called upon for assistance in teaching in the University, or for kindred work; but in no case will they be expected or permitted to devote so much time to this work as to prevent the successful prosecution of their own work as students. Fellows will not engage in outside work for compensation, unless by permission of the President. Except in rare cases, students will not be appointed to Fellowships until they have done at least one year of graduate work.

In addition to the Scholarships mentioned above, one graduate Scholarship, yielding a sum sufficient to pay the annual tuition fees, is annually awarded to the best student in each department graduated from the University of Chicago during the preceding year.

A Scholarship yielding the amount of the tuition fees for three quarters is awarded annually in each department offering Junior College work to the student of highest rank in that department receiving the Associate's title during the preceding year.

Full particulars concerning higher degrees, Fellowships, Scholarships, and other matters of interest to graduate students will be found in the *Circular of Information* of the Colleges and Graduate Schools, which will be sent upon application.

AID TO STUDENTS

Besides Fellowships and Scholarships various kinds of assistance are offered to those who need help, under the following heads: (1) Prizes; (2) University Service; (3) Loans by the Students' Fund Society, and (4) Outside Employment. The position of the University in a large city brings the decided advantage of providing many opportunities for employment. Through the University Employment Bureau many students are able to secure all of the outside employment for which they have time. For further details applicants should send for the circular, *Assistance to Students at the University of Chicago.*

DEGREES

Graduate study may lead to a Master's or to a Doctor's degree under the conditions specified below:

I. THE MASTER'S DEGREE

Two degrees are conferred, viz., *Master of Arts* and *Master of Science.*

1. *Candidacy.*—Any member of the Graduate Schools who has been in attendance one quarter or more, and whose undergraduate course is equivalent to that required for a corresponding Bachelor's degree in the University of Chicago,[1] and whose thesis subject has been accepted by the department concerned, may, on recommendation by the department or departments in which

[1] Attention is particularly called to the fact that the term "equivalent" in this connection refers to quantity only. It does not affect the question of the specific Master's degree (Arts or Science) to which a given student's work would lead.

he is working, be enrolled, by vote of the Faculties of the Graduate Schools, as a candidate for a Master's degree. Application for admission to candidacy must be made on the blank provided for the purpose. This blank must be obtained by the applicant at the Dean's office, and the application must be on file in that office at least two months before the degree is conferred.

2. *Requirements.*—Students thus accepted as candidates will be given a Master's degree on fulfilment of the following requirements:

a) At least three quarters' residence at the University.

b) At least 8 majors of graduate work at the University of Chicago. These 8 majors need not be all in one department, but must be selected according to some rational plan approved by the Deans of the Graduate Schools at least six months before the degree is conferred. The individual courses must receive the approval of the heads of the departments concerned.

c) A satisfactory dissertation on a subject approved by one of the departments in which the work is done.[1] The subject of the dissertation must be approved by the head of the department at least three months before graduation, and the thesis in complete form must be submitted to the department at least four weeks before the degree is conferred. This period may be lengthened to six weeks at the option of any department.

d) The delivery of five printed or typewritten copies of the dissertation to the University Library at least one week before the Convocation at which the degree is to be conferred. One of the copies must be bound.

e) A satisfactory examination on the work taken for the degree.

f) No course completed with a grade below C will count toward the Master's degree.

II. THE DEGREE OF DOCTOR OF PHILOSOPHY

The degree of *Doctor of Philosophy* is given not on the basis of the completion of a certain amount of time spent upon a specified program, but as the recognition and mark of high attainments and ability in the candidate's chosen province, shown, first, by the production of a thesis evincing the power of independent investigation and forming an actual contribution to existing knowledge; and, secondly, by the passing of examinations covering the general field of the candidate's subjects, with more detail in the case of the principal subject, with less detail in the case of the secondary subject or subjects.

1. *Candidacy.*—Any member of the Graduate Schools who has been in attendance one quarter or more, whose undergraduate course is equivalent to that required for a Bachelor's degree in the University of Chicago,[2] whose thesis subject has been accepted by the principal department, and who has a reading knowledge of two modern languages other than English, may, on recommendation by the principal department in which he wishes to take his degree, be enrolled, by vote of the Faculties of the Graduate Schools, as a candidate for the Doctor's degree. The languages other than English must be languages

[1] In exceptional cases the Deans, upon the recommendation of the departments concerned, may accept an additional major in lieu of the dissertation.

[2] In case the candidate did not obtain his Bachelor's degree at the University of Chicago, he will present to the Examiner on blanks furnished for the purpose a detailed statement of his undergraduate work. The Examiner cannot always report upon these statements during the opening week of the quarter.

which contain important critical literature of the subject in which the candidate's principal work is done. They must be selected with the approval of the department of principal work and of the Dean, and a reading knowledge of the languages must be certified by the appropriate departments not less than one academic year (9 months) before the degree is conferred. Application for admission to candidacy must be made on the blank provided for the purpose. This blank must be obtained by the applicant at the Dean's office, and the application must be on file in that office before the close of the quarter preceding that in which the degree is conferred.

2. *Requirements.*—Students accepted as candidates will be given the Doctor's degree on the fulfilment of the following requirements:

a) At least three years of resident work at the University, in pursuance of an accepted course of study (see 5 and 6, p. 11). The course in question must include one principal, and either one or two secondary subjects. The amount of work required in the secondary subject or subjects is normally 9 majors.

b) A satisfactory final examination upon the work done in preparation for the degree.

c) The presentation of a satisfactory thesis upon a subject which has been approved by the Head of the Department in which the principal part of the candidate's work has been done.

d) A good command of literary expression and such knowledge of subjects considered fundamental as may be prescribed by the several departments.

e) Candidates for the degree of Doctor of Philosophy may not, as a rule, take more than two-thirds of their work in one department, and may not take work which is to count toward the degree in more than three departments.

3. *Thesis.*—Each student is required to prepare a thesis upon some topic connected with his principal subject. The thesis must constitute an actual contribution to knowledge. Its subject must be submitted for approval to the Head of the Department at least twelve months before the date of the final examination. The thesis itself must be submitted to the Head of the Department at least one month before the date of the final examination. This period may be lengthened to six weeks at the option of any department.

One week before the Convocation at which the degree is conferred, a typewritten copy of the thesis, together with a certificate signed by the Head or Acting Head of the Department that the copy, as submitted, is accepted for publication as the candidate's thesis for the Doctor's degree, shall be filed in the office of the Deans of the Graduate Schools. Said copy may not be withdrawn from the office of the Deans of the Graduate Schools until the required one hundred copies are deposited in the Library.

The candidate shall deposit in the office of the Deans of the Graduate Schools a contract in legal form to the effect that he will furnish the General Library with one hundred copies (including two bound in half-roan) which shall fufil in format, cover, title-page, and stock all the University requirements.

Any one of the following three methods may be followed:

1) A signed statement may be filed in the Graduate Office from a publishing agency approved as to its technical efficiency by the University Press, and also as to its professional responsibility by the department concerned, that the thesis has been received and accepted for publication.

The one hundred copies furnished to the General Library must be separate prints. They must contain no other material and must be put in covers (ninety-eight in paper covers and two in half-roan).

2) The candidate may deposit with the Business Office a legal financial guaranty sufficient to enable the University Press to print the required one hundred copies, including the binding of two copies in half-roan. This guaranty shall mature at the expiration of two years from the date of the conferring of the degree; or

3) The candidate may at his own cost secure publication of the thesis in the form prescribed by the University, in which case the degree will be conferred only after the delivery of the required one hundred copies to the General Library.

Additional thesis regulations:

a) Upon recommendation of a department and approval of the Dean of the Faculty immediately concerned, a form of the Doctor's thesis briefer than that received in satisfaction of requirements for the degree may be accepted for publication. For instance, the alternative form of publication may be an account of the method pursued in the investigation, together with an abstract of the evidence used and a complete summary of the conclusions reached; or it may be a single chapter, provided the same represents a distinct unit of investigation.

b) In case the briefer form of the Doctor's thesis is accepted for publication, five typewritten copies of the complete thesis are required for deposit in the library in addition to the printed copies.

c) In case the course provided for in (*a*) is adopted, arrangements for the same are made in the Dean's office before the expiration of the term fixed for publication.

d) Clauses (*a*)–(*c*) are held to modify other rules governing publication of theses in the one detail of providing for acceptance of a printed abbreviation in the place of the complete thesis.

4. *Final examination.*—After admission to candidacy the student may present himself for examination in his secondary subject or subjects as soon as he has fulfilled the requirements of the department or departments concerned. He may present himself for the examination in his principal subject, or in both principal and secondary subjects if the examination in the latter has not been taken in advance, (1) as soon as he has fulfilled the requirements of the department or departments concerned, and (2) after he has made satisfactory arrangements as regards his thesis. The examination will be conducted by a committee consisting of the members of the principal department concerned, an appointed representative of the secondary department, or a representative of each of them if there are two, of any other members of the secondary department who may choose to attend, and a member of some other department appointed by the Deans of the Graduate Schools.

If the examination in the secondary subject or subjects is separated from the examination in the principal subject, the two may not be held in the same quarter, nor within two months of each other.

The candidate is required to prepare a typewritten or printed brief of his work, including an analysis of the thesis, and to file six copies of the same with his Dean for distribution to the committee one week before the time set for the examination. In the case of the examination in the secondary department, the

statement should include the work in this department, and the statement for the final examination should include the work of both departments.

5. *Non-resident work.*—After being admitted, the student may be allowed to substitute non-resident work for resident work to a limited extent, under conditions to be arranged in consultation with the Dean and the heads of the departments concerned.

6. *Work done in other universities.*—Graduate work done in another university will be accepted as equivalent to resident work in the University of Chicago, provided the institution in which the work was done is of high standing, and adequate evidence is furnished that the work done there was satisfactorily performed. Graduate work done in other institutions cannot reduce the residence requirement at the University of Chicago to a period less than one year.[1]

[1] In order to avoid misunderstandings, candidates for higher degrees should consult their Deans concerning all technical requirements for such degrees before application is made for admission to candidacy. In all cases candidates should consult early with the heads of the departments of their major and minor subjects.

THE DEPARTMENT OF MATHEMATICS

OFFICERS OF INSTRUCTION

Eliakim Hastings Moore, Ph.D., LL.D., Sc.D., Math.D., Professor and Head of the Department of Mathematics.

Oskar Bolza, Ph.D., Non-Resident Professor of Mathematics (Freiburg i.B.).

Herbert Ellsworth Slaught, Ph.D., Professor of Mathematics.

George William Myers, Ph.D., Professor of the Teaching of Mathematics and Astronomy, the School of Education.

Leonard Eugene Dickson, Ph.D., Professor of Mathematics.

Gilbert Ames Bliss, Ph.D., Professor of Mathematics.

Ernest Julius Wilczynski, Ph.D., Professor of Mathematics.

Jacob William Albert Young, Ph.D., Associate Professor of the Pedagogy of Mathematics.

Arthur Constant Lunn, Ph.D., Assistant Professor of Applied Mathematics.

Derrick Norman Lehmer, Ph.D., Associate Professor of Mathematics, University of California (Summer, 1917).

George David Birkhoff, Ph.D., Assistant Professor of Mathematics, Harvard University (Summer, 1917).

FELLOWS, 1916–17

Kenneth W. Lamson, A.B. — Flora Elizabeth Le Stourgeon, A.M.

Irwin Roman, A.M. — Thomas McNider Simpson, Jr., A.M.

John Sidney Turner, A.B.

GENERAL STATEMENT

The regular Junior College courses are courses 1, 2, 3, 6, and 15.

Students who expect to specialize in Mathematics, Astronomy, or Physics should confer with the instructors in Mathematics in planning their courses. They should take courses 1, 2, 3, 18, 19, and 20. It is possible, however, for students of exceptional ability in Mathematics to pass from course 2 to course 18, if course 3 is taken at the same time as course 18. Students who desire to have at least a glimpse beyond the elements of mathematics should elect courses 3 and 15.

The following courses introductory to the Higher Mathematics are intended both (1) for students making Mathematics their principal subject, and (2) for those making Mathematics their secondary subject, in particular for students of Astronomy and Physics: (A) †Differential and integral calculus with applications (3Mj.); (B) †Solid analytics; selected topics in geometry; theory of equations; determinants and elementary invariants; (C) †Analytic mechanics (2Mj.); vector analysis; celestial mechanics (2Mj.); theory of the potential; (D) †Advanced calculus, †differential equations, †theory of definite integrals, elliptic integrals, Fourier series and Bessel functions, elements of the theory of functions; (E) Synthetic projective geometry; analytic projective geometry; differential metric geometry; differential projective geometry; (F) Theory of numbers; theory of invariants; selected chapters of algebra; theory of substitutions with applications to algebraic equations; less quaternions.

Groups (A)–(F) indicate six sequences of courses running through the usual academic year from October to June. These sequences vary slightly from year to year; the courses marked (†) are given annually, and the other courses usually once in two years.

The undergraduate student who wishes to specialize in Mathematics should take courses of group (A) as Junior College electives, of (B) in his first Senior College year, and of (C) and (D) in his second Senior College year.

The courses of groups (A)–(F) and the special courses in the Higher Mathematics are intended to give the graduate student a comprehensive view of modern mathematics, to develop him to scientific maturity, and to enable him to follow, without further guidance, the scientific movement of the day in mathematics, and, if possible, to take an active part in it by creative research. The special and research courses vary from year to year. They may be classified, in general, as relating to (*a*) Algebra and Arithmetic; (*b*) Analysis; (*c*) Geometry; (*d*) Mechanics and Applied Mathematics; and (*e*) the Foundations and Interrelations of the Mathematical Disciplines as purely abstract deductive systems. Attention is called to courses of type (*d*) offered by the Departments of Astronomy and Physics.

The proper arrangement of courses is a matter of extreme importance; the best arrangement for any student depends on his previous mathematical studies, and should be determined by conference with some member of the Department.

The courses of the Summer Quarter are designed to meet the needs of those college men and others wishing to study Advanced Mathematics, who are able to spend only the summer in residence. The courses of a series of four summer quarters are arranged so as to give a wide view of modern mathematics.

Scholarship examinations.—The competitive examinations for the Senior College Scholarship and for the Graduate Scholarship in Mathematics are held each Spring Quarter at times and places announced in the *Weekly Calendar*. Prospective candidates should confer with the Departmental Examiner in Mathematics. Files of papers set at previous Scholarship examinations are accessible in the Departmental Library. Candidates for the Senior College Scholarship will be examined on courses 1, 2, and 3; those for the Graduate Scholarship on courses 18, 19, 20, 31, 32, 47, 48, and 49.

Models.—A collection of Brill's models: plaster and thread models of quadric surfaces, plaster models of cubic and Kummer's quartic surfaces, models of cyclides and surfaces of constant positive and negative curvature, and thread models of three-dimensional projections of four-dimensional regular bodies.

LIST OF COURSES FOR UNDERGRADUATES

1. Plane Trigonometry (if taken in college); 2, College Algebra; 3, Analytic Geometry; 6, College Geometry; 15, Introductory Calculus; 18, Differential Calculus; 19, Integral Calculus; 20, Application of Calculus; 21, Advanced Calculus; 23, 24, Theory of Equations; 29, 30, Projective Geometry, I, II; 31, Solid Analytics; 34, 35, Limits and Series; 37, Critical Review of Secondary Mathematics; 38, Synoptic Course in Mathematics; 47, Differential Equations; 48, Elliptic Integrals; 49, Definite Integrals; 50, Fourier Series and Bessel Functions.

MATHEMATICAL SEQUENCES FOR UNDERGRADUATES

All courses offered by the Department of Mathematics or given numbers in its printed Announcements (called "mathematical majors" in what follows) may

be used in mathematical sequences, except those whose numbers begin with 0. Courses admissible for sequences in the Departments of Physics and Astronomy may also be used in mathematical sequences to an amount not greater than one-third of the total number of majors.

Principal sequences.—A principal sequence may consist of any nine admissible majors provided at least three mathematical majors are included whose numbers are higher than 17.

Secondary sequences.—A secondary sequence may consist of any six admissible majors provided at least one mathematical major is included whose number is higher than 14.

The admissible Junior and Senior College courses in mathematics now listed are enumerated above, and from these the sequences will ordinarily be chosen; but in exceptional cases mature students might select certain more advanced courses, such as: 91, Introduction to Higher Algebra; 101, Theory of Functions of a Real Variable; 121, Theory of Functions of a Complex Variable; 160, Vector Analysis. In such cases, and in all cases of doubt as to the arrangement of sequences, students should consult the departmental officers.

The following are given as illustrations of typical sequences:

PRINCIPAL SEQUENCES

a) Courses 1, 2, 3, 18, 19, 20, 47, 48, 49.
b) Courses 1, 2, 3, 18, 19, 23, 24, 31, 38.

SECONDARY SEQUENCES

a) Courses 1, 2, 3, 18, 19, 20.
b) Courses 1, 2, 3, 15, 23 or 29, 31 or 34.

MATHEMATICS AND ASTRONOMY

Principal Sequences

a) Courses 1, 2, 3, 18, 19, 20, Astronomy and Astrophysics 5, 6, 7.
b) Courses 1, 2, 3, 18, 19, Astronomy and Astrophysics 3A, 3B, 4.

Secondary Sequences

a) Courses 1, 2, 3, 15, Astronomy and Astrophysics 1, 7.
b) Courses 1, 2, 3, 15, Astronomy and Astrophysics 3A, 3B.

MATHEMATICS AND PHYSICS

Principal Sequences

a) Courses 1, 2, 3, 18, 19, 47, Physics 3, 4, 5.
b) Courses 1, 2, 3, 15, 23, 24, Physics 3, 4, 6.

Secondary Sequences

a) Courses 1, 2, 3, 15, Physics 3, 4.
b) Courses 1, 2, 3, 23, Physics 3, 4.

SEQUENCES FOR PROSPECTIVE TEACHERS

Principal Sequences

a) Courses 1, 2, 3, 18, 19, 23, 31, 37, 38.
b) Courses 1, 2, 6, 15, 26, 32, 34, 36 or 37, 39.

Secondary Sequences

Courses 1, 2, 3, 15, 23 or 31, 37 or 38.

Students preparing to teach mathematics in secondary schools, either as a major or as a minor subject, should take Education 66, Educational Psychology, and 1, Principles of Education, and should take practice teaching in the School of Education.

MATHEMATICAL CLUBS

The Departmental Club meets regularly for the review of memoirs and books, and for the presentation of results of research. The club is conducted by the members of the Faculties of Mathematics and Mathematical Astronomy. Graduate students of the Departments are expected to attend and otherwise to participate in the meetings of the club.

The Junior Mathematical Club, with fortnightly meetings, is conducted by the graduate students of the Departments of Mathematics and of Astronomy and Astrophysics.

HIGHER DEGREES

Master's degree.—Candidates for the Master's degree in Mathematics are expected, on the basis of a principal sequence of nine majors of undergraduate mathematics, to offer for examination eight approved courses of groups (*a*)–(*e*), including the elements of the theory of functions, and to present a satisfactory thesis on an assigned topic closely related to the subject of one of the courses.

Degree of Doctor of Philosophy.—Candidates for the Doctor's degree with Mathematics as secondary subject are expected to offer for examination nine approved courses in advance of course 3.

Candidates for the Doctor's degree with Mathematics as principal subject are expected (1) to offer for examination the subjects covered by fifteen majors of initial courses of groups (B)–(F), including two of each of the types (*a*)–(*e*), and by a considerable body of special courses, in each case presumably most closely related to the subject of the doctoral dissertation, and (2) to present a dissertation, in finished form, embodying valuable results of mathematical inquiry. The subject of the dissertation may be a topic of pure or applied mathematics or of the history, philosophy, or pedagogy of mathematics.

PREPARATION FOR TEACHING

Courses in the history and the teaching of Elementary Mathematics—Arithmetic, Algebra, Geometry, Trigonometry, Analytic Geometry, Calculus, Mechanics—are offered by this Department and the School of Education. These courses embody the conviction that elementary students need to have their mathematics made, not easier, but more perfectly intelligible and attractive. To this end it is believed that teachers should more generally appreciate and utilize in instruction the unity of mathematics, as made up of various closely interrelated parts, and the character of mathematics, as an ideal science developed by abstraction from various more concrete domains.

A) *Secondary-school positions.*—Students who expect to teach mathematics as a major subject in secondary schools should complete at least the following courses in their undergraduate career: (1) Courses in pure mathematics: Trigonometry, College Algebra, Plane Analytic Geometry, Differential and Integral Calculus and Applications of Calculus, Theory of Equations, and the Synoptic course; (2) Courses in applied mathematics: Descriptive Astronomy, Mechanics,

and General Physics; (3) The two courses, Principles of Education and Methods of Education, which may be taken either in the Junior College or in the Senior College; (4) Practice teaching in mathematics in the University High School, for which the foregoing courses in education are prerequisite; (5) A course in the Teaching of Secondary Mathematics and a course in the History of Secondary Mathematics.

B) *Minor collegiate positions.*—Those who look forward to teaching mathematics in normal schools and small colleges should as undergraduates complete at least the following courses: (1) The general courses in education and those in the history and teaching of mathematics mentioned in (3) and (5) above; (2) The content courses specified in (1) and (2) above, together with Advanced Calculus (3 majors).

Candidates for these positions should take at least one year of graduate work leading to the Master's degree in Mathematics and during this year should visit some of the college courses in Mathematics with the purpose of observing methods of teaching. It is the intention of the Department to offer such candidates opportunity, as far as possible, to act as assistants in connection with the collegiate classes, in order that they may gain experience through both observation and practice.

C) *University positions.*—Candidates for university positions should qualify for the Doctor's degree. Courses in the history of mathematics and in the principles and practice of education are strongly recommended.

COURSES OF INSTRUCTION

I. JUNIOR COLLEGE COURSES

00. Advanced Algebra.[1]—A collegiate treatment of quadratic equations and other topics of the third semester of algebra of the secondary school. For students who offer only one unit of mathematics for entrance. Mj. Autumn, MR. ———.

01, 02. Plane Geometry I, II.[1]—A collegiate treatment of plane geometry for students who offer no geometry for entrance. Two consecutive majors. Winter and Spring, MR. ———.

1. Plane Trigonometry.—Mj. Summer, PROFESSOR SLAUGHT; Autumn, 3 sections, ASSOCIATE PROFESSOR LAVES, MR. ———, AND MR. ———; Winter, 2 sections, ASSISTANT PROFESSOR LUNN AND MR. ———; Spring, PROFESSOR SLAUGHT AND MR. ———.

2. College Algebra.—Prerequisite: course 1. Mj. Summer, 2 sections, PROFESSOR WILCZYNSKI; Autumn, MR. ———; Winter, ASSOCIATE PROFESSOR YOUNG; Spring, MR. ———.

3. Analytic Geometry.—Elements of plane analytics, including the geometry of the conic sections, with an introduction to solid analytics. Prerequisite: courses 1 and 2. Mj. Summer, ASSOCIATE PROFESSOR LEHMER; Autumn, PROFESSOR MOORE; Winter, ASSOCIATE PROFESSOR YOUNG; Spring, ASSOCIATE PROFESSOR YOUNG.

15. Introductory Calculus.—The elementary fundamental principles, methods, and formulas of differential and integral calculus will be carefully studied in connection with simple problems of geometry and the physical sciences. This course is intended primarily for those who do not wish to take the longer course in Calculus (courses 18, 19, and 20). Prerequisite: course 1. Mj. Spring, ASSOCIATE PROFESSOR YOUNG.

[1] Full credit only if taken as one of the first eighteen majors.

II. SENIOR COLLEGE COURSES

18, 19, 20. Calculus I, II, III.—A development of the three fundamental notions of the Calculus: the derivative, the anti-derivative, the definite integral, with especial emphasis on their geometrical interpretations and their relations to problems in geometry, mechanics, and physics. Prerequisite: courses 1, 2, and 3. Three consecutive majors. Autumn, Winter, and Spring, 2 sections, Professors Bliss, Slaught, and Mr. ——.

18, 19. Calculus I, II.—Prerequisite: courses 1, 2, and 3. Two consecutive majors. Winter and Spring, Professor Wilczynski.

18. Calculus I: Differential Calculus.—A graphic study of rational algebraic functions and of certain simple irrational transcendental functions, yielding material for a geometric introduction to the fundamental notions and processes of the Calculus. Prerequisite: courses 1, 2, and 3. Mj. Summer, Associate Professor Young.

19. Calculus II: Integral Calculus.—A course aimed at a comprehension of the nature of integration and of its applications to geometry and physics; solution of numerous problems; use of table of integrals. Prerequisite: course 18. Mj. Summer, Assistant Professor Birkhoff.

21. Advanced Calculus.—Selected topics in the Differential and Integral Calculus requiring more extensive and theoretical treatment than is given in courses 18 and 19: for example, development of the formulas for successive differentiation and the differentiation of implicit functions, Taylor's formula with applications, transformation of variables in different equations and multiple integrals, line integrals and partial integration of multiple integrals. Prerequisite: courses 18 and 19. Mj. Autumn, Assistant Professor Lunn.

22. Elementary Theory of Equations.—The course covers those sections of Dickson's *Elementary Theory of Equations* which are not marked by a dagger. Prerequisite: Differential Calculus. Mj. Winter, 1919, Professor Dickson.

23. Theory of Equations I.—Graphical methods, solution of numerical equations, Sturm's functions, introduction to complex numbers, algebraic solution of cubic and quartic equations. Text: Dickson's *Elementary Theory of Equations*. Prerequisite: Differential Calculus. Mj. Autumn, Professor Dickson.

24. Theory of Equations II.—Determinants, symmetric functions, resultants and discriminants, fundamental theorem of algebra, theory of geometrical constructions. Mj. Winter, Professor Dickson.

28. Selected Topics in Mathematics.—Based on certain parts of the ten "Monographs on Topics of Modern Mathematics Relevant to the Elementary Field," edited by J. W. A. Young. Mj. [Not given in 1917–18.]

29. Synthetic Projective Geometry.—A development of projective geometry from the purely synthetic standpoint. Fundamental forms of the first and second orders; conic sections and surfaces of the second order; involution with applications; quadratic transformations, plane systems, point systems and space systems projectively related, with some study of space curves and of line geometry. Mj. Summer, Associate Professor Lehmer.

29, 30. Projective Geometry I, II.—The fundamental notions of projective geometry treated both analytically and synthetically. The method of abbreviated notation and homogeneous co-ordinates. Theory of determinants and their application to the geometry of two and three dimensions. Projective and dualistic transformations and the simpler Cremona transformations. Notions of group and invariant. Prerequisite: courses 1, 2, 3, 18, 19. Two consecutive majors. Winter and Spring, 1920, Professor Wilczynski.

31. Solid Analytics.—This course may be taken simultaneously with course 18; it is an advisable antecedent of course 19. Prerequisite: courses 3 and 18. Mj. Summer, Associate Professor Young; Spring, Professor Dickson.

34. Limits and Series.—Definitions and fundamental properties of various types of limits. Prerequisite: Differential and Integral Calculus. Mj. Spring, PROFESSOR MOORE.

35. Series.—Theory of infinite series with applications. Prerequisite: Differential and Integral Calculus. M. Summer, First Term, PROFESSOR MOORE.

The Teaching of Elementary-School Mathematics (School of Education: Mathematics 1).—Mj. Winter, PROFESSOR MYERS.

The Teaching of Secondary Mathematics (School of Education: Mathematics 2).—Mj. Spring, PROFESSOR MYERS.

History of Mathematics (School of Education: Mathematics 5).—Mj. Winter, PROFESSOR MYERS.

37. Critical Review of Secondary Mathematics.—A brief survey of the subject-matter of Secondary Mathematics from the modern point of view, aiming both to organize the theory of the whole scientifically and to gather the products of this work for use in teaching. Primarily for teachers, actual and prospective, but open also to others. Mj. Summer, ASSOCIATE PROFESSOR YOUNG. [Not given in 1917.]

38. Synoptic Course in Advanced Mathematics.—A general historical and logical survey of a considerable portion of pure and applied mathematics. Prerequisite: courses 1, 2, and 3. Mj. PROFESSOR WILCZYNSKI. [Not given in 1917–18.]

Analytic Mechanics, I, II. (Astronomy 5, 6).—An introductory course. Prerequisite: Mathematics 18, 19. 2Mjs. Autumn and Winter, ASSOCIATE PROFESSOR LAVES.

47. Differential Equations.—A study of the more common types of ordinary differential equations, especially those of the first and second orders, with emphasis on geometrical interpretations and applications to geometry, elementary mechanics, and physics. Prerequisite: courses 18, 19, and preferably 20. Mj. Summer, PROFESSOR SLAUGHT; Autumn, PROFESSOR SLAUGHT.

48. Elliptic Integrals.—A systematic development of the theory of indefinite integration, leading to elliptic integrals and the elements of elliptic functions, with attention to problems and applications. This course includes also an introduction to Fourier series. Prerequisite: courses 18, 19, 20, and preferably 46 or 47. Mj. PROFESSOR SLAUGHT. [Not given in 1917–18.]

49. Theory of Definite Integrals.—A course treating of the properties and methods of computing definite integrals, including a study of methods of approximation, improper definite integrals, Eulerian integrals, multiple integrals, with many problems and applications. Prerequisite: course 47. Winter, PROFESSOR MOORE.

50. Fourier Series and Bessel Functions.— (*a*) A study of the properties of Bessel functions in connection with the solution of a variety of physical problems where they occur directly. (*b*) Trigonometric and Bessel series as solutions of partial differential equations. Byerly's "Fourier Series." Mj. Spring, ASSISTANT PROFESSOR LUNN. [Not given in 1918.]

III. GRADUATE COURSES

NOTE.—Students should register for graduate courses only after consultation with instructors.

65A, B, C, D. Reading and Research in Pure Mathematics.—When in the judgment of the Department it is advisable that students undertake definite mathematical reading and research not closely connected with any current lecture course or seminar, this work will be directed by PROFESSOR MOORE, PROFESSOR DICKSON, PROFESSOR BLISS, OR PROFESSOR WILCZYNSKI. Mj. or DMj. each Quarter.

66A, B, C. Reading and Research in Applied Mathematics.—Advisable reading and research will be directed by PROFESSOR MOORE, PROFESSOR MYERS, OR ASSISTANT PROFESSOR LUNN. Mj. or DMj. each Quarter.

71. Theory of Numbers.—Introductory course. Theory of congruences, the quadratic reciprocity theorem, and the theory of quadratic forms. Mj. Autumn, 1919, PROFESSOR DICKSON.

74. Theory of Algebraic Numbers.—Prerequisite: course 71. Mj. Winter, 1920, PROFESSOR DICKSON.

75. History of the Theory of Numbers.—Development from the historical standpoint of fundamental topics in the theory of numbers. The course is an introductory one, open to Senior college students after consultation with the instructor. Mj. Spring, PROFESSOR DICKSON.

81. Substitution Groups and Algebraic Equations.—An introduction to the theory of groups of substitutions and the Galois theory of algebraic equations, with applications to geometry. Text: Miller, Blichfeldt and Dickson's *Theory and Applications of Finite Groups*. Mj. Winter, PROFESSOR DICKSON.

82. Finite Groups.—Selected topics on substitution groups, abstract groups, finite linear and collineation groups. Text as in course 81. Mj. Spring, 1919, PROFESSOR DICKSON.

84. Continuous Groups.—An illumination of the fundamental concepts and theorems of the Lie theory in connection with various classes of problems of geometry and differential equations. Mj. Summer, 1918, PROFESSOR BLISS.

91. Introduction to Higher Algebra.—Properties of matrices, invariant factors, and elementary divisors; algebraic theory of a single quadratic or bilinear form; theory of pairs of quadratic or bilinear forms. Geometrical applications. Based largely upon Bôcher's *Introduction to Higher Algebra*. Mj. Autumn, PROFESSOR DICKSON.

93. Theory of Algebraic Invariants.—An introduction to the non-symbolic theory of invariants of binary forms, with applications to geometry, followed by an explanation of the symbolic notation, with practice in its use. Based on Dickson's *Algebraic Invariants*. Mj. Winter, 1919, PROFESSOR DICKSON.

98. Linear Algebras.—An introduction to the theory of hypercomplex numbers, with attention to quaternions, the relations of the theory to matrices, bilinear forms, and groups. Text: Dickson's *Linear Algebras*, 1914, Cambridge Tracts on Mathematics and Mathematical Physics. Mj. Spring, 1920, PROFESSOR DICKSON.

101. Theory of Functions of a Real Variable.—A study of the existence theorems for implicit functions, ordinary and partial differential equations, and their applications in Analysis, especially to the Calculus of Variations. Mj. Autumn, 1919, PROFESSOR BLISS.

102. Ordinary Linear Differential Equations of the Second Order.—Existence theorems (real case), the analogy between linear algebraic and linear differential equations, theorems of comparison and oscillation, characteristic numbers and functions, expansion of arbitrary functions, Green's functions. Prerequisite: an elementary knowledge of the theory of functions of a real variable. Mj. Summer, ASSISTANT PROFESSOR BIRKHOFF.

104. Calculus of Variations.—Examples illustrating the various types of problems. The differential equations of a curve which minimizes a definite integral in a space of two or more dimensions. Other properties of a minimizing curve as deduced by Legendre, Weierstrass, and Jacobi for the case of the plane. Conditions which insure the existence of a minimum. Isoperimetric problems and the more general problems of Lagrange and Mayer. An introduction to the theory for double integrals. Prerequisite: course 101. Mj. Winter, 1920, PROFESSOR BLISS.

105. Functions of Lines.—Special cases which occur in the calculus of variations and the theory of integral equations. The derivations of Volterra

and the differentials of Fréchet, with applications to maxima and minima and implicit functions. The theory of composition of functions and the solution of general types of integral and integro-differential equations. Prerequisite: course 104. Mj. Spring, 1920, PROFESSOR BLISS.

106. Partial Differential Equations.—The geometrical theory of equations of the first order. Linear equations. Systems of equations of the first order. Introduction to equations of the second order. Applications to geometry and physics. Mj. Spring, 1919, PROFESSOR BLISS.

108. Differential Equations from the Standpoint of Lie.—The relations between continuous groups and differential equations. The Picard-Vessiot theory of linear differential equations. Mj. Winter, 1919, PROFESSOR BLISS.

111. Classes of Functions and Functional Operations in General Analysis.—Based on Moore's *Introduction to a Form of General Analysis.* The general analysis in question is the theory of systems of classes of functions, functional operations, etc., involving at least one general variable on a general range. A general variable is a variable entering the theory without direct characterization as to quality or range of variation. A real- and single-valued function ξ of a general variable p has as especially important particular instances: (I) a real number ξ, the variable p having only one value; (II) an n-partite real number $\xi=(\xi_1, \ldots, \xi_n)$, or point ξ in real space of n dimensions, the variable p having the values $p=1, 2, \ldots, n$; (III) an infinite sequence $\xi=(\xi_1, \xi_2, \ldots, \xi_n, \ldots)$ of real numbers, the variable p having the values $p=1, 2, \ldots, n, \ldots$; (IV) a function ξ or $\xi(p)$ of the variable p on the linear interval $0\leqq p\leqq 1$ of the real number system. The first part of this introductory course considers certain fundamental closure and dominance properties of classes of functions of a general variable, properties possessed in particular by the class: (I) of all real numbers; (II) of all n-partite real numbers; (III_0) of all numerical sequences converging to zero; (III_1) of all absolutely convergent series of real numbers; (IV) of all continuous functions of p on the interval $0\leqq p\leqq 1$. The course presupposes a knowledge of the elements of the theory of functions of real variables. For second-year graduate students. Mj. Autumn, PROFESSOR MOORE.

112. Matrices in General Analysis.—Definitely positive hermitian matrices and associated integration processes. For second-year graduate students. Mj. Autumn, 1918, PROFESSOR MOORE.

113, 114. Theory of Functions of Infinitely Many Variables in General Analysis.—Prerequisite: course 112. Two consecutive majors. Winter, Spring, 1919.

115, 116. Integral Equations in General Analysis.—Application of the methods of course 111 to a study of the general Fredholm and Hilbert-Schmidt theories of integral equations. Two consecutive majors. Winter, Spring, PROFESSOR MOORE.

119. Spectrum of Limited Symmetric Infinite Matrix.—A sketch of Hellinger's treatment of the theory of Hilbert. M. Summer, PROFESSOR MOORE.

121. Theory of Functions of the Complex Variable.—Introduction to the algebra and calculus of complex numbers and their geometric representation; conform representation. The theory of power series and the properties of analytic functions. Introduction to the theory of Riemann surfaces. Prerequisite: courses 47 and 49. Mj. Summer, ASSISTANT PROFESSOR LUNN; Autumn, PROFESSOR BLISS.

122. Algebraic Functions.—The analytic character of an algebraic function and its geometrical representation by means of a Riemann surface. Abelian integrals on the Riemann surface, with especial attention to the hyperelliptic case. Abel's theorem. Introduction to the theory of the inversion of Abelian integrals. Prerequisite: course 121. Mj. Winter, PROFESSOR BLISS.

123. Elliptic Functions.—Elliptic integrals and the Weierstrassian theory of elliptic functions. Applications of elliptic functions. Mj. Spring, PROFESSOR BLISS.

130. Foundations of Geometry.—A critical study of geometry by the method of postulates based on the work of Hilbert and his successors. Mj. Spring, PROFESSOR MOORE. [Not given in 1918.]

141. Analytic Projective Geometry.—Analytic treatment of the projective properties of the straight line and of the conic sections. Prerequisite: familiarity with the fundamental concepts of projective geometry and a good knowledge of the calculus. Mj. Summer, 1918.

142. Higher Plane Curves.—General properties of algebraic curves. Special study of the curves of the third and fourth order. Mj. Autumn, PROFESSOR WILCZYNSKI. [Not given in 1917.]

144. Line Geometry.—The line co-ordinates of Plücker and Klein. Complexes, congruences, and ruled surfaces. Prerequisite: course 31. Mj. [Not given in 1917–18.]

145. Higher Geometry.—A general survey of the principal methods and results of recent geometric research. The various systems of co-ordinates and space elements, the rôle of the group concept, and the cultivation of space intuition by the use of models. Prerequisite: Differential Equations, Projective Geometry, and Solid Analytic Geometry. Mj. Spring, 1919, PROFESSOR WILCZYNSKI.

151, 152. Metric Differential Geometry.—The application of the Calculus to the metric theory of twisted curves and surfaces in space. Prerequisite: course 31. Two consecutive majors, Winter, Spring, PROFESSOR WILCZYNSKI.

154, 155.—Projective Differential Geometry, I, II.—This course gives a brief account of Lie's theory, with applications to the theory of invariants of systems of linear differential equations. The projective differential properties of plane and space curves, of surfaces and congruences, then present themselves as a result of interpreting this invariant theory geometrically. Text: Wilczynski's *Projective Differential Geometry of Curves and Ruled Surfaces.* (B. G. Teubner, Leipzig, 1906.) Prerequisite: an elementary knowledge of differential equations and projective geometry. Two consecutive majors, Autumn, 1918, Winter, 1919, PROFESSOR WILCZYNSKI.

154. Projective Differential Geometry.—Mj. Summer, PROFESSOR WILCZYNSKI.

156. Theory of Plane Curves.—Projective and metric differential and integral properties. Texts: Salmon's *Higher Plane Curves* and Wilczynski's *Projective Differential Geometry of Curves and Ruled Surfaces.* Prerequisite: an elementary knowledge of differential equations and projective geometry. Mj. PROFESSOR WILCZYNSKI. [Not given in 1917–18.]

157. Theory of Ruled Surfaces and Space Curves.—Primarily from the point of view of projective differential geometry. Text: Wilczynski's *Projective Differential Geometry of Curves and Ruled Surfaces.* Prerequisite: course 156. Mj. PROFESSOR WILCZYNSKI. [Not given in 1917–18.]

158. Theory of Surfaces and Congruences, with special emphasis upon the projective differential properties.—Prerequisite: Mathematics 157. Mj. PROFESSOR WILCZYNSKI. [Not given in 1917–18.]

160. Vector Analysis.—The elements of vector algebra, vector differentiation and integration, and the linear vector function; illustrated by typical applications to geometry, mechanics, and physics. Prerequisite: courses 31 and 49. Mj. Summer, 1918, Autumn, 1919, ASSISTANT PROFESSOR LUNN.

162. Applications of Vector Analysis in the Theory of Electromagnetism.—Formulation of the Maxwell-Lorentz theory in terms of vector analysis. Hydrokinetic analogies and the geometry of scalar and vector fields. Fundamental problems in integration. Introductory study of vectors in four dimensions. Prerequisite: course 160. Mj. Winter, 1920, ASSISTANT PROFESSOR LUNN.

163. Theory of Attraction and the Potential.—The potential function of gravitation and electrostatics; Laplace's equation, Green's functions, and harmonic analysis; extensions to cases of heterogeneous media, with sketch of the

abstract theory as related to linear differential equations of the second order. Emphasis will be laid on the solutions of illustrative problems. Pierce's *Newtonian Potential Function.* Prerequisite: courses 49 and 160. Mj. Autumn, ASSISTANT PROFESSOR LUNN.

164. Dynamics of Oscillatory Systems.—Mj. Autumn, 1918, ASSISTANT PROFESSOR LUNN.

166. Hydrodynamics.—Kinematics of continuous media and dynamical theory of typical forms of motion in perfect and viscous fluids, with special emphasis on analytic methods of general use in mathematical physics. Mj. Winter, 1919, ASSISTANT PROFESSOR LUNN.

167. Theory of Elasticity.—The geometry of strain in a continuous medium, dynamical relations of stress and strain; detailed study of selected problems in the equilibrium and motion of elastic solids. Prerequisite: Advanced Calculus and Analytic Mechanics. Mj. ASSISTANT PROFESSOR LUNN. [Not given in 1917–18.]

170. Probability and Statistics.—The theory of average and probability for finite and infinite sets of elements; the statistical treatment of observations and the method of least squares; introduction to statistical mechanics, with examples from the theories of molecules and electrons. Prerequisite: Differential Equations. Mj. ASSISTANT PROFESSOR LUNN. [Not given in 1917–18.]

171. Statistical Mechanics.—This course deals with the mathematical methods used in the treatment of those physical theories where the magnitudes directly accessible to measurement are conceived as averages of multitudes of elements and physical laws are interpreted as examples of statistical regularity. A brief preparatory treatment of the notions of statistics and of the main features of the theory of probability, with some examples in geometry and kinematics, will lead to the main work of the course, in the kinetic theory of gases, the electron theory of metals, and some aspects of the theory of radiation. Prerequisite: thorough knowledge of the Calculus. Mj. Winter, ASSISTANT PROFESSOR LUNN. [Not given in 1918.]

172. Partial Differential Equations of Mathematical Physics; the Conduction of Heat.—A study of certain typical linear partial differential equations occurring in the analytic representation of physical theories and of the functional expansions of solutions satisfying given boundary conditions, with special reference to the concrete phenomena and physical analogies from which the abstract theory has been generalized. Prerequisite: courses 49 and 160. Mj. Winter, ASSISTANT PROFESSOR LUNN.

178. The Theory of Relativity.—After a brief historical introduction on the notion of relativity of time and space in its classic or Newtonian form, the course will be devoted to a study of the recent theory initiated by Einstein and Minkowski as a geometry of space and time adapted to the representation of physical laws. Special attention will be given to the discrimination between the logical elements of the theory and the special concrete interpretations that may be used in the formulation of experimental results. Mj. Summer, ASSISTANT PROFESSOR LUNN.

CONSPECTUS OF COURSES OFFERED BY THE DEPARTMENT OF MATHEMATICS, 1917–18

Summer, 1917	Autumn, 1917	Winter, 1918	Spring, 1918
1. Plane Trigonometry (Slaught)	00. Advanced Algebra (———)	01. Plane Geometry I (———)	02. Plane Geometry II (———)
2. College Algebra (Wilczynski)	1. Plane Trigonometry (*a*) (Laves) (*b*) (———) (*c*) (———)	1. Plane Trigonometry (*a*) (Lunn) (*b*) (———)	1. Plane Trigonometry (*a*) (Slaught) (*b*) (———)
3. Analytic Geometry (Lehmer)	2. College Algebra (———)	2. College Algebra (Young)	2. College Algebra (———)
18. Differential Calculus (Young)	3. Analytic Geometry (Moore)	3. Analytic Geometry (Young)	3. Analytic Geometry (Young)
19. Integral Calculus (Birkhoff)	18. Calculus I (*a*) (Bliss) (*b*) (Slaught)	19. Calculus II (*a*) (Bliss) (*b*) (———)	15. Introductory Calculus (Young)
29. Synthetic Projective Geometry (Lehmer)	21. Advanced Calculus (Lunn)	18. Calculus I (Wilczynski)	20. Calculus III (*a*) (Bliss) (*b*) (Slaught)
31. Solid Analytics (Young)	23. Theory Equations I (Dickson) Analytic Mechanics I (Laves)	24. Theory Equations II (Dickson) Analytic Mechanics II (Laves)	19. Calculus II (Wilczynski)
35. Series (First Term) (Moore)	47. Differential Equations (Slaught)	49. Definite Integrals (Moore)	31. Solid Analytics (Dickson)
47. Differential Equations (Slaught)	91. Higher Algebra (Dickson)	81. Substitution Groups and Algebraic Equations (Dickson)	34. Limits and Series (Moore)
102. Linear Differential Equations Second Order (Birkhoff)	111. Introduction General Analysis (Moore)	115. Integral Equations in General Analysis I (Moore)	75. History Theory Numbers (Dickson)
119. Spectrum of Infinite Matrix (First Term) (Moore)	121. Functions Complex Variable (Bliss)	122. Algebraic Functions (Bliss)	116. Integral Equations in General Analysis II (Moore)
121. Functions Complex Variable (Lunn)	163. Attraction and Potential (Lunn)	151. Metric Differential Geometry I (Wilczynski)	123. Elliptic Functions (Bliss)
154. Projective Differential Geometry (Wilczynski)		172. Partial Differential Equations of Mathematical Physics: Conduction of Heat (Lunn)	152. Metric Differential Geometry II (Wilcyznski)
178. Theory of Relativity (Lunn)			

THE DEPARTMENT OF ASTRONOMY AND ASTROPHYSICS

OFFICERS OF INSTRUCTION

EDWIN BRANT FROST, A.M., SC.D., Professor of Astrophysics; Director of the Yerkes Observatory.

SHERBURNE WESLEY BURNHAM, A.M., SC.D., Emeritus Professor of Practical Astronomy at the Yerkes Observatory.

EDWARD EMERSON BARNARD, A.M., SC.D., LL.D., Professor of Practical Astronomy at the Yerkes Observatory.

FOREST RAY MOULTON, PH.D., Professor of Astronomy.

KURT LAVES, PH.D., Associate Professor of Astronomy.

JOHN ADELBERT PARKHURST, S.M., Assistant Professor of Practical Astronomy at the Yerkes Observatory.

STORRS BARROWS BARRETT, A.B., Assistant Professor of Astrophysics; Secretary and Librarian of the Yerkes Observatory.

WILLIAM DUNCAN MACMILLAN, PH.D., Assistant Professor of Astronomy.

GEORGES VAN BIESBROECK, DR.ENG., Assistant Professor of Practical Astronomy at the Yerkes Observatory.

OLIVER JUSTIN LEE, S.M., PH.D., Instructor in Practical Astronomy at the Yerkes Observatory.

HANNAH BARD STEELE, A.M., Assistant in Practical Astronomy.

GEORGE SPENCER MONK, S.B., Assistant in Stellar Spectroscopy.

FELLOWS, 1916–17

ISRAEL ALBERT BARNETT, S.B. EDWIN POWELL HUBBLE, S.B., A.B.

INTRODUCTORY

The work of the Department of Astronomy and Astrophysics is divided into two parts: (1) Work at the University, comprising: (*a*) elementary instruction in general Astronomy, both theoretical and practical; (*b*) preliminary training in the principles and methods of work underlying the science of Astrophysics (given in part in the Department of Physics); (*c*) graduate and research work in Celestial Mechanics. (2) Graduate and research work in Practical Astronomy and Astrophysics in the Yerkes Observatory at Williams Bay, Wisconsin. (1) At the University, in the work given by Professor Moulton, Associate Professor Laves, and Assistant Professor MacMillan, emphasis will be laid on the development of the mathematical principles and methods which form the basis of the physical sciences. In addition to the courses in Descriptive Astronomy, Introduction to Celestial Mechanics, and Analytic Mechanics, courses on Periodic Orbits and in the various other branches of Celestial Mechanics will be given within periods not exceeding three years. The most fundamental subjects will be arranged so as to recur at regular intervals, while other more special topics will vary from time to time. The general object of the instruction will be to give experience and preliminary training in the work of observation and reduction; to furnish the student an adequate mathematical basis for successful work in Celestial Mechanics, and to direct research work in Celestial Mechanics. The

Departmental Club meets fortnightly for the review of memoirs and books, and for the presentation of results of research. The club is conducted by the members of the Faculties of Mathematics and Mathematical Astronomy. Graduate students of Mathematical Astronomy are expected to attend regularly and, so far as possible, to participate actively in the meetings of the club. (2) At the Yerkes Observatory, the advanced student is made familiar with modern methods of research in various branches of Practical Astronomy and Astrophysics. The rapid development of the latter science within the last two decades has been fully recognized in the equipment of the Observatory; the special laboratory facilities make some investigations possible which cannot be carried on where the equipment is less complete. In general, the work in progress during the year 1917–18 will include: Researches in solar physics with the spectroscope, spectroheliograph, and photoheliograph; micrometric observations of double stars, planets, satellites, nebulae, and comets; studies of photographic stellar spectra and determinations of motions in the line of sight; photography of stars, comets, nebulae, etc.; photographic investigations of stellar parallax; research in visual and photographic photometry; special astrophysical researches. The opportunity of taking part in these investigations is deemed of more advantage to the qualified student than set courses of instruction; but regular programs of work, with courses of collateral reading, will be laid out as conditions require. During the Summer Quarter illustrated lectures particularly intended for graduate students are given on one evening of each week by members of the staff. The Astronomical Club also meets regularly—weekly during the Summer Quarter—for the discussion of assigned topics in Astronomy and Astrophysics.

FACILITIES

For instruction in Practical Astronomy a students' observatory is maintained. It is equipped with a modern Warner & Swasey equatorial telescope of 6½ inches aperture, which is provided with a filar micrometer; a 5-inch refractor; a 3-inch Bamberg transit instrument; a Bamberg universal instrument; a Riefler sidereal clock; a chronometer, and various smaller accessories. The laboratory courses offered by the Department of Physics afford excellent preliminary training for the work in Astrophysics.

For a description of the Yerkes Observatory see the *Annual Register* of the University of Chicago, Part V. An illustrated pamphlet of 24 pages, describing the observatory in detail, may be obtained on application.

DEGREES

The Master's degree.—Students working for a Master's degree in Astronomy are advised to choose three majors of graduate work in the Department of either Mathematics or Physics and six majors in the Department of Astronomy, from courses numbered 5 to 10, 22, and 23. Those working for the Master's Degree in Practical Astronomy or Astrophysics at the Yerkes Observatory are not required to spend part of their time at the University, although this is advised where possible.

The degree of Doctor of Philosophy.—The courses prescribed for the Master's degree together with three other graduate courses will meet the requirement for the Doctor's degree, where astronomy is the minor subject.

Candidates for the Doctor's degree, with Astronomy as major subject, are expected to make their secondary subject either Mathematics or Physics. Students intending to specialize in the lines of Astrophysics will be required to take the work in Theoretical Physics, Advanced Experimental Physics, Sound and Light, and Physical Manipulation. The courses in Astronomy which will be required depend on the phase of the subject which the candidate elects for his work. Students specializing in Celestial Mechanics are expected to spend six months at the Yerkes Observatory, and those working in Practical Astronomy and Astrophysics are expected to spend at least two quarters at the University.

COURSES OF INSTRUCTION

SEQUENCES

3A and B, Descriptive Astronomy; 2, Spherical Trigonometry, with applications; 5, 6, Analytic Mechanics; 7A and B, Practical Astronomy; 10, Spectroscopy and Astrophysics; 22, 23, Celestial Mechanics; Mathematics 3, Analytic Geometry; 18, 19, Calculus; Physics 3, Mechanics, Molecular Physics, Heat; 4, Electricity, Sound, and Light.

The Department offers no nine-major sequences.

SECONDARY SEQUENCES

I. Astronomy

Courses 3A, 3B, 2, 7A, 7B, 10.

II. Astronomy and Mathematics

Courses 3, 18, 19 in Mathematics, 5, 6, 22 in Astronomy.

III. Astronomy and Physics

Courses 3A, 3B, Physics 3, 4, Astronomy 10, 7.

A. JUNIOR COLLEGE COURSES

1. Descriptive Astronomy (shorter course).—An elementary course, dealing with fundamental facts, principles, and methods. Frequent access to the students' observatory. Mj. Summer, PROFESSOR MOULTON; Spring, PROFESSOR MOULTON AND ASSISTANT PROFESSOR MACMILLAN.

2. Spherical Trigonometry with Applications to Astronomy.—Prerequisite: Plane Trigonometry. Mj. Winter, ASSOCIATE PROFESSOR LAVES.

3A and 3B. Descriptive Astronomy (longer course; 1 not prerequisite).—A two-quarter course dealing with the fundamental facts and principles of Astronomy. Modern as well as classical methods and results are brought into full discussion. The observational side of the subject also is emphasized. Prerequisite: Plane Trigonometry. Mj. Winter and Spring, ASSISTANT PROFESSOR MACMILLAN.

4. Introduction to Surveying (Mathematics 1).—Mj. Spring, ASSOCIATE PROFESSOR LAVES.

B. SENIOR COLLEGE COURSES

5. Analytic Mechanics (Statics).—An introductory course. Prerequisite: Mathematics 18, 19. Mj. Autumn, ASSOCIATE PROFESSOR LAVES.

6. Analytic Mechanics (Dynamics).—Prerequisite: Mathematics 18, 19. Mj. Winter, ASSOCIATE PROFESSOR LAVES.

7. Spherical and Practical Astronomy.—Determination of time, latitude, and longitude. Prerequisite: Astronomy 1 and Mathematics 3. Mj. Spring, ASSOCIATE PROFESSOR LAVES; Summer, ASSISTANT PROFESSOR MACMILLAN.

8. Practical Astronomy I.—Observations of binary stars and determination of their orbits. Mj. Autumn, Associate Professor Laves. [Not given in 1917–18.]

9. Practical Astronomy II.—Observations of satellites and determination of orbits of satellites. Mj. Autumn, Associate Professor Laves.

10. Spectroscopy and Astrophysics (Physics 24).—A non-technical treatment of the growth of Spectroscopy, with applications to solar and stellar phenomena. Mj. Spring, Professor Gale.

C. GRADUATE COURSES

22. Introduction to Celestial Mechanics I.—Gravitational theory of sun's heat, central forces, potential and attraction of finite bodies, properties of conic section motion. Prerequisite: Mathematics 18, 19. Mj. Summer and Winter, Assistant Professor MacMillan.

23. Introduction to Celestial Mechanics II.—Determination of orbits, special cases of the problems of three bodies: the Lunar Theory geometrically considered; variation of the elements and absolute perturbations. Mj. Spring, Assistant Professor MacMillan.

25. The Dynamics of Stellar Systems.—Prerequisites 22 and 23. In this course are included such topics as the dynamics of various types of multiple stars, star clusters, variable stars, and nebulae; the various types of stellar organizations, gallaxies and super gallaxies; the distribution of stars in space; dimensions of the physical universe. Mj. Summer, Professor Moulton.

31–36. Research Courses at the Yerkes Observatory.—The Yerkes Observatory is open only to graduate students who have completed the necessary preliminary studies and have had the requisite experience in practical laboratory and observatory work. Students wishing to work at the Observatory should first consult the Director of the Yerkes Observatory, Williams Bay, Wis., and obtain his approval. DMj. or 3Mjs. each Quarter, Professors and Instructors resident at Yerkes Observatory.

41. Theory of Planetary Motion.—Prerequisite: Astronomy 22 and 23. Mj. Autumn, Professor Moulton. [Not given in 1917.]

42. The Lunar Theory.—Prerequisite: Astronomy 22 and 23, Mathematics 121. Mj. Winter, Professor Moulton.

43. Application of the Methods of Periodic Orbits to the Lunar Theory.—Prerequisite: Astronomy 42. Mj. Spring, Professor Moulton.

51, 52. Modern Theories of Analytic Differential Equations with Applications to Celestial Mechanics and Periodic Orbits I, II.—Properties of the solution of a general system of differential equations of the nth order as functions of the independent variable, of the parameters, of the initial values of the dependent variables. Solutions developed as power series in the independent variable, in the parameters, in the initial values of the dependent variables, by the Cauchy-Lipschitz process, by the Picard approximation process, by continued variation of parameters. Applications to elliptic and hyperelliptic functions and to periodic solutions of the problem of three bodies. Linear equations with applications to hypergeometric functions. Linear equations with periodic coefficients. Mj. Autumn and Winter, Professor Moulton.

60. Periodic Solutions of the Problem of Three Bodies.—Mj. Professor Moulton. [Not given in 1917.]

70. Theory of Figures of Equilibrium of Rotating Fluid Bodies.—This is an advanced course, including Poincaré's and Darwin's researches. Mj. Professor Moulton. [Not given in 1917.]

80. The Problem of Three Bodies.—Mj. Professor Moulton. [Not given in 1917–18.]

THE DEPARTMENT OF PHYSICS

OFFICERS OF INSTRUCTION

Albert Abraham Michelson, Ph.D., Sc.D., LL.D., F.R.S., Professor and Head of the Department of Physics.
Robert Andrews Millikan, Ph.D., Sc.D., Professor of Physics.
Henry Gordon Gale, Ph.D., Professor of Physics.
†Charles Riborg Mann, Ph.D., Associate Professor of Physics.
Carl Kinsley, A.M., M.E., Associate Professor of Physics.
Harvey Brace Lemon, Ph.D., Instructor in Physics.
Wilmer Henry Souder, Ph.D., Assistant in Physics.
Karl Ketchner Darrow, S.B., Assistant in Physics.
Arthur Jefferey Dempster, Ph.D., Assistant in Physics.
Charles Frederick Hagenow, A.M., Assistant in Physics.
Otto Koppius, S.B., Assistant in Physics.
Yoshio Ishida, Ph.D., Assistant in Physics.
Earnest Charles Watson, Ph.B., Assistant in Physics.
†Resigned.

FELLOWS, 1916–17

Edward Stowe Akeley, A.B.
Oswald Hance Blackwood, A.B.
Helen Turnbull Gilroy, A.M.
Merwin Joe Kelley, S.B.
Otto Koppius, S.B.
Leland Johnson Stacey, A.B.
Margaret Shields, A.B.

INSTRUCTIONAL WORK

The instructional work in Physics is directed toward the following ends: (1) The training of original investigators in physics; (2) the training of men competent to fill college and university positions as teachers of physics; (3) the training of teachers of physics for secondary schools; (4) the training of pre-engineering and pre-medical students for later professional work; (5) the training of the general student in scientific methods of work, and in the understanding of the place of physical science in the modern world. From the most elementary to the most advanced courses, the laboratory and the problem method of instruction are emphasized.

FACILITIES

The Ryerson Physical Laboratory has been enlarged and remodeled with especial reference to offering the best facilities for research work. The entire lower floor and basement are given up to private research rooms. A well-equipped shop, with skilled instrument-makers, furnishes opportunity for the construction of special pieces of research apparatus. The equipment has been selected with reference to the needs of research, and includes spectroscopic instruments of highest power, electrical apparatus for work in alternating and direct currents through all ranges of potential, and appliance for high and for low temperature work, including a liquid-air plant. The library of the Department is well equipped for research purposes. A Physics Club is conducted by the members of the Department, and meets regularly for the discussion of the results of research work done in the Ryerson Laboratory and elsewhere.

SEQUENCES

3, Mechanics, Molecular Physics, and Heat; 4, Electricity, Sound, and Light; 5, Lecture Demonstration Course; 6, General Survey of Physical Science; 10, Elementary Mathematical Physics; 11, Heat and Molecular Physics; 12, Light; 13, Electricity and Magnetism; 14, Pedagogy of Physics; 15, Mechanics and Wave Motion; 16, 17, 18, 19, Experimental Physics; 20, Physical Manipulation; 21, Analytic Mechanics; (Astronomy 5, 6), 25, History of Physical Science; 26, Teaching Physical Science; Education 62, Educational Psychology; 1, Principles of Education; Astronomy 3, Descriptive Astronomy (two majors); Mathematics 18, 19, Calculus.

Graduate courses in the Department may be substituted for courses 10 to 19 by students who have the prerequisites.

PRINCIPAL SEQUENCES

a) Courses 3, 4, 5, and any six majors chosen from courses 10 to 13; 15 to 19.

Physics and Mathematics

b) Courses 3, 4, 5, and any six majors from the following: Mathematics 18, 19; Astronomy 5, 6, and Physics 10 to 13; 15 to 18.

Teachers' Sequences

c) Courses 3, 4, 5, 14, 20, 25, 26, and Education 62 and Philosophy 7.

Physics and Astronomy

d) Courses Physics 3, 4, 5; Astronomy 3, (two majors), with four majors selected from Physics 10–18, and Mathematics 18, 19.

Physics and Chemistry

e) Courses Physics 3, 4, 5; Chemistry 2S, 3S, and four majors selected from Physics 10–18, 18, and Mathematics 18, 19.

In any of the foregoing sequences graduate courses numbered 31 to 61 may be substituted for courses 10 to 18 by students who have the required prerequisites.

SECONDARY SEQUENCES

a) Courses 3, 4, 5, and three advanced majors in Physics.

b) Courses 3, 4, 5, and three majors from the following: 10 to 61, Astronomy 3 (two majors), Chemistry 2S, 3S; Mathematics 18, 19.

DEGREES

All candidates for the S.B. degree who elect their major work in Physics are required to take courses 3, 4, and 5, and either six majors selected from courses 10, 11, 12, 13, 15, 16, 17, 18, 19, 24, and 25, or three of these and three Senior College courses in one of the following departments: Mathematics, Astronomy, Chemistry, Geology, or Geography.

The Master's degree.—Candidates for the Master's degree in Physics are required to take eight majors in Physics and related subjects, and to present in addition a thesis embodying the results of a laboratory problem. All courses in the Department numbered 10 or above, except course 20, will be counted in satisfaction of this requirement, but at least three majors selected from courses 10, 11, 12, 13, and 15 must be included.

The degree of Doctor of Philosophy.—Candidates for the Doctor's degree with Physics as a minor subject must take six of the following courses: 10, 11, 12, 13, 15, 16, 17, 18, 19, 24, 25, and three additional majors of graduate work.

When Physics is one of two minor subjects, the courses must be arranged by consultation with the Department.

All candidates for the Doctor's degree with Physics as the major subject must take the following courses: 10, 11, 12, 13, 15, and 25, or their equivalent; three majors selected from courses 16, 17, 18, 37, 38, and 39; courses 31–36, and three additional graduate courses selected by the student. Each candidate must also present a thesis embodying the results of original research in some subject approved by the Department. The time required for the thesis work generally varies from three to six quarters.

PREPARATION FOR TEACHING

Students preparing to teach Physics in secondary schools are expected to have completed courses 3, 4, 5 or 6, 14 or 26, and not less than four of courses 10, 11, 12, 13, 15, 16, 17, 18, 19, 24, and 25. See also courses in Physics in the School of Education.

LABORATORY FEE

There is a laboratory fee of $5.00 for all major courses involving laboratory work in the Department of Physics.

COURSES OF INSTRUCTION

I. JUNIOR COLLEGE COURSES

1. Elementary Physics.[1]—A first course in the elements of Physics designed primarily for students who do not present entrance Physics. DM. Summer, First Term, MR. KOPPINS AND MR. DARROW; Mj. Autumn, ———.

2. Elementary Physics.[1]—A continuation of the preceding course, covering the subjects of electricity, sound, and light. Prerequisite: course 1. DM. Summer, Second Term, MR. KOPPINS AND MR. DARROW; Mj. Winter, ———.

3. Mechanics.—A general college course in mechanics presented mainly from the experimental point of view, but including one demonstration lecture each week. Prerequisite: entrance Physics or course 2. Mj. Autumn, 5 sections, DR. LEMON, DR. SOUDER, AND DR. DEMPSTER.

4. Heat, Electricity I.—A general college course in molecular physics and heat, and beginning electricity, presented mainly from the experimental point of view, but including one demonstration lecture each week. Prerequisite: course 3. Mj. Winter, 4 sections, DR. LEMON, DR. SOUDER, AND DR. DEMPSTER.

5. Electricity II, Sound and Light.—A general college course continuing electricity from course 4, and followed by sound and light, presented mainly from the experimental point of view, but including one demonstration lecture each week. Prerequisite: course 4. Mj. Spring, 4 sections, DR. LEMON, DR. SOUDER, AND DR. DEMPSTER.

6. General Survey of Physical Science.—A lecture demonstration course in which familiar physical phenomena are presented and discussed with reference both to their scientific interpretation and to their relations to modern life. Prerequisite: entrance Physics or course 2. Mj. Spring, ———.

3S. Mechanics, Molecular Physics and Heat.—A general college course in mechanics, molecular physics and heat presented from the experimental point of view, not containing demonstration lectures. Prerequisite: entrance Physics or course 2 and Trigonometry. Mj. Summer, 2 sections; Winter, 2 sections, DR. SOUDER AND MR. WATSON.

[1] Full credit only if taken as one of the first eighteen majors.

4S. Electricity, Sound, and Light.—A general college course in electricity, sound, and light presented from the experimental point of view, not containing demonstration lectures. Prerequisite: course 3S or courses 3 and 4. Mj. Summer, 2 sections; Spring, 2 sections, DR. SOUDER AND MR. WATSON.

7. Lecture Demonstration Course.—A course of demonstration lectures covering the entire field of Physics designed to supplement courses 3S and 4S. Especial attention is given to modern points of view; the Kinetic theory of heat, the atomic theory of electricity, and the electrical theory of matter receiving especial attention. The attempt is made to repeat a majority of the classical demonstrations of Kelvin, Faraday, Thomson, and others. This course includes the demonstration lectures of courses 3, 4, and 5. Prerequisite: courses 3S and 4S or their equivalent. Mj. Summer, PROFESSOR WILLIAMS AND DR. DEMPSTER.

II. SENIOR COLLEGE COURSES

10. Elementary Mathematical Physics.—A lecture course on the application of Elementary Calculus to Physics and Chemistry, and practice in the solution of problems. Prerequisite: Physics 4S or 5 and not less than one major of Calculus. Mj. Autumn, PROFESSOR GALE.

11. Heat and Molecular Physics.—A lecture course for advanced and graduate students, covering the Kinetic Theory, Capillarity, Elementary Thermodynamics, Solution, and Electrolysis. Prerequisite: Physics 4S or 5 and Calculus. Mj. Autumn, PROFESSOR MILLIKAN.

12. Light.—A lecture course for advanced students covering the more important sections of geometrical and physical optics. Prerequisite: Physics 4S or 5 and Calculus. Mj. Summer and Winter, PROFESSOR GALE.

13. Electricity and Magnetism.—A course of advanced work in Theoretical Electricity and Magnetism, with many applications to electrical and magnetic apparatus and measurements. Prerequisite: Physics 4S or 5 and Calculus. Mj. Winter, ASSOCIATE PROFESSOR KINSLEY.

14. The Pedagogy of High-School Physics.—This course includes the following topics: the present high-school course in Physics, its development, requirements, and methods of presentation; the principles involved in the lecture demonstration, in the recitation and quiz, and in the laboratory experiments and notebook. The course is illustrated by a series of lecture demonstrations. It provides a survey of the whole field of Physics, with a special reference to the choice of subject-matter and effective methods of presentation in high-school classes. Prerequisite: a thorough knowledge of the first principles of Physics. Lecture, 9:00; Laboratory, 7:00. DMj. Summer, MR. WILKINS.

15. Mechanics and Wave-Motion.—A lecture course on the physical meaning and the mathematical derivation of the fundamental equations of Mechanics and Wave-Motion. Prerequisite: Physics 4S or 5 and Calculus. Mj. Spring, PROFESSOR GALE.

16. Experimental Physics (Advanced): Molecular Physics and Heat.—A course of advanced laboratory work involving the determination of vapor pressures and densities, coefficients of friction of gases and liquids, molecular electrical conductivities, freezing- and boiling-points, latent and specific heats, high and low temperatures, radioactive constants, etc. Prerequisite: course 4S or 5. Mj. Spring, PROFESSOR MILLIKAN AND DR. SOUDER; Summer, DR. SOUDER.

17. Experimental Physics (Advanced): Light.—A course of advanced laboratory work in Light, consisting of accurate measurements in diffraction, dispersion, interference, and polarization. Prerequisite: course 4S or 5. Mj. Summer and Autumn, PROFESSOR GALE.

18. Experimental Physics (Advanced): Electricity and Magnetism, I.—Laboratory work of the same grade as courses 16 and 17, but consisting of measurements in Electricity and Magnetism. Prerequisite: Physics 4S or 5. Mj. Summer and Winter, ASSOCIATE PROFESSOR KINSLEY.

19. Experimental Physics (Advanced): Electricity and Magnetism, II.—Laboratory work accompanied by lectures consisting of the theory and operation of dynamos, motors, transformers, wireless-telegraph apparatus. Prerequisite: Physics 4S or 5. Mj. Spring, ASSOCIATE PROFESSOR KINSLEY.

20. Physical Manipulation.—A series of exercises not provided in the regular courses of Experimental Physics, but important to the teacher or advanced student. It consists of the following groups:

Group A. *Shop Work* includes the cutting, filing, drilling, tapping, soldering, and polishing of metal, screw cutting, and elementary lathe work.

Group B. *Glass Work* includes the cutting, grinding, drilling, polishing, and testing of glass.

Group C. *Glass Blowing* includes the simpler processes in glass blowing, such as cutting, bending, and joining of tubes, blowing bulbs, sealing in electrodes, etc.

Group D. *Chemical Processes and Physical Preparations* include the silvering of glass, cleaning and distillation of mercury, preparation of fibers for suspension, and materials useful in experimental work. Group C only M. First Term. Repeated Second Term, Summer, MR. PAYNE.

22. For teachers who are familiar with the laboratory practice of high-school Physics. This course consists of the lecture part only of course 14. Mj. Summer, MR. WILKINS.

24. Spectroscopy and Astrophysics.—A non-technical treatment of the growth of Spectroscopy, with applications to solar and stellar phenomena. Prerequisite: 15 majors. Mj. Spring, PROFESSOR GALE.

28. Photographic Processes.—Lectures and laboratory work on the laws of photographic action. Effects of exposure and development on opacity and density; orthochromatism, plate grain, speed, intensification, reduction, and the applications of these to the photography of exceptional subjects. Prerequisite: Calculus. Mj. DR. LEMON. [Not given in 1917–18.]

III. GRADUATE COURSES

31, 32, 33. Theoretical Physics.—A series of lectures chiefly in Theoretical Physics, Hydrodynamics, Elasticity, Capillarity, Molecular Physics, Thermodynamics, Wave-Motion, Sound, Optical Theories, Electricity, and Magnetism. 4 hours a week. Prerequisite: Physics 10, 11, and 13 and Calculus. Mj. Autumn, Winter, and Spring, PROFESSOR MICHELSON.

34, 35, 36. Theoretical Physics.—A series of lecture courses. Alternating with 31, 32, and 33. Prerequisite: same as for course 31. 3Mjs. Autumn, Winter, and Spring, PROFESSOR MICHELSON.

37, 38, 39. Experimental Physics.—A course of laboratory work, chiefly devoted to the repetition of classical experiments, such as Determination of the Mechanical Equivalent of Heat; Maxwell's "V"; Hertzian Oscillations; Relative and Absolute Wave-Lengths, etc. 10 hours a week. Prerequisite: Physics 16, 17, and 18. 3Mjs. Autumn, Winter, and Spring, PROFESSORS MICHELSON AND MILLIKAN.

40, 41, 42, 43. Research Course.—This course is intended for graduate students who are prepared to undertake special research. Except in the case of a purely mathematical problem, the entire time is to be devoted to work in the laboratory. DMj. Autumn, Winter, and Spring, PROFESSORS MICHELSON AND MILLIKAN.

48. Spectrometry I.—Laboratory work in photographing and measuring the spectra of various elements. Use of the concave grating, echelon, and interferometer. Prerequisite: consent of the instructor. Mj. Winter, PROFESSOR GALE.

49. Spectrometry II (continuation of course 48).—Mj. or DMj. Spring, PROFESSOR GALE.

51. Thermodynamics.—Lectures upon the fundamental principles underlying the mechanical theory of heat and the application of these principles to physical and thermochemical problems. Prerequisite: two years of college Physics and Calculus. 5 hours a week. Mj. Winter, PROFESSOR MILLIKAN.

52. Electron Theory I.—A course of graduate lectures covering the work of the last ten years on the electrical properties of gases, the electron theory, and radioactivity. Prerequisite: same as for course 51. 5 hours a week. Mj. Spring, PROFESSOR MILLIKAN.

53. Electron Theory II.—A continuation of 52, dealing with the application of the electron theory to metallic conduction, to the Seebeck, Peltier, Thomson, and Hall effects, to optical phenomena in magnetic fields, to the subject of electromagnetic mass, etc. 5 hours a week. Mj. PROFESSOR MILLIKAN. [Not given in 1917–18.]

55. Atomic Theories of Radiation and Their Experimental Basis.—A course of graduate lectures on recent theories of radiation, with especial reference to their relations to the laws of thermodynamics. Prerequisite: Elementary Thermodynamics. Mj. Spring, PROFESSOR MILLIKAN.

56. X-Rays and Theories of Atomic Structure.—A course of graduate lectures dealing with X-rays and the related phenomena, the study of which has thrown new light upon the structure of the atom and the relations of the atom and the molecule. Prerequisite: College Physics and Calculus. Mj. 8:00, PROFESSOR MILLIKAN. [Not given in 1917–18.]

57. The Theory of Alternating Currents.—A discussion of transformers, transmission circuits, and the various types of dynamos and motors. Prerequisite: course 18 or 19 and Calculus. Mj. ASSOCIATE PROFESSOR KINSLEY.

58. Transient Electrical Phenomena.—Theory and demonstration of current flow before the steady state is reached. Oscillations in power circuits and wireless-telephone and -telegraph transmission are discussed. Prerequisite: course 18 or 19 and Calculus. Mj. Spring and Summer, ASSOCIATE PROFESSOR KINSLEY.

59. Modern Spectroscopy.—A lecture course on the theory and use of spectroscopic apparatus and a discussion of spectroscopic and astrophysical phenomena. Prerequisite: same as course 51. Mj. PROFESSOR GALE. [Not given in 1917–18.]

60. Light Waves and Their Uses.—A course of graduate lectures on recent developments in physical optics. Prerequisite: same as for course 51. Mj. PROFESSOR MICHELSON. [Not given in 1917–18.]

61. Physical Optics.—Lectures on the fundamental equations of Theoretical Optics and on recent experimental results. Prerequisite: same as for course 51. Mj. Summer, PROFESSOR GALE. [Not given in 1917–18.]

62. The Theory of Relativity.—After a brief historical introduction on the notion of relativity of time and space in its classic or Newtonian form, the course will be devoted to a study of the recent theory initiated by Einstein and Minkowski as a geometry of space and time adapted to the representation of physical laws. Special attention will be given to the discrimination between the logical elements of the theory and the special concrete interpretations that may be used in the formulation of experimental results. Mj. Summer, ASSISTANT PROFESSOR LUNN.

63. Geometrical Optics.—The methods and principles of Geometrical Optics as applied to the designing of optical instruments and the interpretation of their performance. Theory of the ideal instrument and its approximate realization; aberrations; illumination and diffraction; special properties of particular instruments; characteristics of various types of optical glass. Mj. ASSISTANT PROFESSOR LUNN. [Not given in 1917–18.]

64. Electromagnetic Theory.—(*a*) The main experimental facts of electromagnetism and their generalization so far as covered by the Maxwell theory in its abstract form; special problems concerning steady fields, induction, and electromagnetic waves. M. First Term, Summer; (*b*) The electronic interpretation and extension of the Maxwell theory; electromagnetic mass; theory of radiation and conduction; problems relating to moving bodies. Mj. ASSISTANT PROFESSOR LUNN. [Not given in 1917–18.]

65. Theory of Wireless Telegraphy.—The fundamental laws and their application to the wireless telegraph circuits of the various operating systems. Prerequisite: Physics 13, 18, or 19, and Calculus. ½Mj. Summer, ASSOCIATE PROFESSOR KINSLEY.

66. Electrical Measurements in Wireless Telegraphy.—Experimental verification of wireless telegraph theories and the measurement of constants at high frequencies. Prerequisite: registration in 65. ½Mj. Summer, ASSOCIATE PROFESSOR KINSLEY.

67. Quantum Theory.—This course will cover the theoretical and experimental development of the radiation laws out of which grew the first suggestion of an atomic theory of radiant energy. It will give a critical survey of the attempts to interpret the newer discoveries in the domain of specific heats in terms of the Quantum theory and will deal also with the photo-electric X-ray and optical phenomena which lend support to such a theory. Mj. (or M. either Term), Summer, PROFESSOR MILLIKAN.

68. Theory of Sound.—Its production, registration, reproduction, transmission, with the methods of measurement. General theory of acoustical and musical instruments, together with parallelism in wireless telegraphy. Original apparatus will be shown. M. First Term, 9:15, PROFESSOR WEBSTER.

69. Physical Optics.—A theoretical treatment of optical phenomena in the realm of interference and dispersion. M. First Term, Summer, PROFESSOR MICHELSON.

70. Physics Club.—This organization, consisting of all instructors and graduate and advanced students in the Department, meets on Thursday of each week from 4:30 to 6:00 for the discussion of recent research.

THE DEPARTMENT OF CHEMISTRY

OFFICERS OF INSTRUCTION

Julius Stieglitz, Ph.D., Sc.D., Chem.D., Professor and Chairman of the Department of Chemistry.
Herbert Newby McCoy, Ph.D., Professor of Chemistry.
William Draper Harkins, Ph.D., Professor of Chemistry.
Hermann Irving Schlesinger, Ph.D., Assistant Professor of Chemistry.
Jean Felix Piccard, Sc.Nat.D., Assistant Professor of Organic Chemistry.
Ethel Mary Terry, Ph.D., Instructor in Chemistry.
John William Edward Glattfeld, Ph.D., Instructor in Chemistry.
T. Dale Stewart, Ph.D., Instructor in Chemistry.
Willis Eugene Gouwens, Curator.
Raymond David Mullinix, S.B., Associate and Lecture Assistant.
Ralph Kempton Strong, Ph.D., Associate in General Chemistry.
William DeGarmo Turner, S.B., Associate in General Chemistry.
Edward N. Roberts, B.S., Assistant in Chemistry.
Quaesita Cromwell Drake, A.B., A.M., Research Assistant.
Leo Finkelstein, B.S., Assistant in Physical Chemistry.
Henry Russell Curme, S.B., Assistant in Organic Chemistry.
Harry Clyde Trimble, A.B., Assistant in Chemistry.
Earl C. H. Davies, S.B., Assistant in General Chemistry.
Elmer N. Bunting, Assistant in Quantitative Analysis.
Lester Aronberg, S.B., Assistant in Chemistry.
Louis M. Larsen, S.B., M.S., Assistant in Chemistry.

Martin A. Rosanoff, Professor of Theoretical Chemistry, The University of Pittsburgh, Professorial Lecturer, Spring Quarter, 1917.
Moses Gomberg, Ph.D., Professor of Organic Chemistry, University of Michigan, First Term, Summer Quarter, 1917.
Stanley Davis Wilson, Ph.D., Assistant Professor of Chemistry, Rice Institute (Summer Quarter).

FELLOWS, 1916–17

Ralph Lyman Brown, A.B., Swift Fellow.
George L. Clark, S.B., S.M.
Adeline de Sale, S.B., Edith Barnard Fellow.
David McLaren, A.M.
Lathrop Emerson Roberts, S.B.
John Edward Schott, S.B.
Herman Vance Tartar, S.B., Loewenthal Fellow.

INSTRUCTIONAL WORK

The Department aims to prepare students (1) to teach in colleges or universities; (2) to teach in secondary schools; (3) to fill positions as technical experts or assistants in chemical industries; (4) to become analysts in commercial and sanitary laboratories. The elementary courses may be taken with advantage by students having none of these ends in view.

Special stress will be placed on thoroughness of preparation and the symmetrical development of the student's knowledge. The object of the courses will be not so much to train specialists as to prepare the student to undertake intelligently all kinds of work of a chemical nature. Those intending to become practical chemists will find a thorough course of purely scientific chemistry the best basis for future specialization in any branch of the subject. Those who incline toward inorganic chemistry will be required to do much physical and a considerable amount of organic work; those proposing to become organic chemists will be required to do work in inorganic chemistry of a more advanced nature than that given in the elementary and analytical courses, and some physical chemistry, etc.

RESEARCH

Students are encouraged to begin research work as soon as their preparation justifies it. Facilities for research in all lines, whether of inorganic, organic, or physical chemistry, are provided. Special opportunities to pursue entirely independent research work, as guests of the University (see page 6), will be given to maturer students who have already obtained the Doctor's degree. Besides a number of general University Fellowships which are usually allowed to the department for candidates for the Ph.D. degree, there are three specially endowed Fellowships in Chemistry: The Loewenthal Fellowship, a memorial to Joseph B. Loewenthal, the Swift Fellowship, endowed by Mrs. Gustavus F. Swift, and the Edith Barnard Fellowship, a memorial to Edith Ethel Barnard.

ARRANGEMENT OF COURSES

2, 3, 2S, 3S, General Chemistry, Inorganic; 4, Elementary Organic; 6, 7, 10, Qualitative Analysis; 8, 9, Quantitative Analysis; 12, Spectrum Analysis; 13–19, Special Methods in Quantitative Analysis; 20, Assaying; 25, Toxicology; 26, Detection of Poisons; 30–49, Organic Chemistry; 50–56, Advanced Inorganic Chemistry; 60–71, Physical Chemistry; 80, Teaching of Chemistry; 90–100, Research.

REQUIREMENTS FOR DEGREES

THE DEGREE OF DOCTOR OF PHILOSOPHY

I. *Chemistry the primary subject.*—When the degree of Doctor of Philosophy in Chemistry is desired, the branch of chemistry touched by the thesis is offered as a *major subject* and some other branch of chemistry as the *first minor* subject. Besides this, a sufficient knowledge of other fundamental phases of the science is required as well as sufficient work in a *second minor* subject in some other department. These conditions are complied with when the following specific requirements are fulfilled:

1. The presentation of a thesis embodying the result of original research in General, Inorganic, Organic, Physico-organic, or Physical Chemistry, or Radioactivity. This must constitute a real contribution to knowledge, and the work is usually done under the direction of an officer of the Department.

2. The general requirements for all candidates, in advance of General Chemistry: courses 4,[1] 6–9, 60 or 61 or 62, and two majors selected from courses 10, 11, 13–19, 30–32.

[1] Course 4 may be omitted when advanced work in Organic Chemistry is taken.

3. In addition to the above, one of the following specific sets of requirements, arranged according to the thesis subject:

General Chemistry and Inorganic Chemistry: courses 35 (or 30 and 31), 50–52, and 63, and one major taken from courses 13–19, 30–37, 64; *Organic Chemistry:* courses 30–32, 35[1]–37, 50, and one major from 10, 13–19, 51, 52, 63, 64; *Physico-organic Chemistry:* courses 30, 31, 35, 36, 50, and 63, and one major taken from courses 10, 13–19, 51, 52, 63, and 64. *Physical Chemistry:* courses 35 (or 30 and 31), 50, 51, 63, 64, and one major taken from courses 10, 13–19, 30–32, 35–37, 52. *Radioactivity:* courses 50, 51, 63, 68, 69, and Physics 52 (Electron Theory), and one major taken from courses 10, 13–19, 30–32, 35–37, 52, and 64. In addition to one set of these specific requirements at least six half-majors will be chosen from the special lecture course 40–45, 54–58, 65–76, 83. The research work will require from four to six quarters.

4. Sufficient work of an advanced character in another department to make a *second minor* of *three majors*. In addition to the regular minor subject, candidates are advised to take Mineralogy and Crystallography. The following are the requirements for such a minor in various departments: *a*) In *Physics:* three of the courses 11, 12, 13, 16, 17, 18, 19, 48, 49, 51, 52, 53, 55 or 56; courses 3, 4, 5 are prerequisite to these. *b*) In *Physiological Chemistry:* three other majors selected from 24, 25, 26, 37, 38, 39, or 42. *c*) In *Geology:* courses 15, 16, and 52 or their equivalent. Course 7 or 8, and 11, 12, 14 would be prerequisite to these courses. *d*) In *Geography:* Courses 17, 18, 21, and their prerequisite courses. *e*) In *Hygiene and Bacteriology:* Course 12 and 2½ majors in course 15; courses 2 and 3 are prerequisite to these. With permission, course 10 or 11 may be substituted for course 12.

II. *Chemistry the secondary subject.*—When Chemistry is a secondary subject, the requirement is determined after conference with the Head of the Department in which the major work is done. Courses 6, 7, and 8, and six other majors in advance of 8, will be required when Chemistry is the only secondary subject; courses 6, 7, and 8, and three other majors, when Chemistry is one of two secondary subjects. Elementary Physical Chemistry or Organic Chemistry, according as the major subject belongs to the Physical or the Biological Group, is recommended.

THE MASTER'S DEGREE

For the Master's degree a dissertation and eight majors of graduate work in Chemistry are required if all the work is in Chemistry. These majors must be selected from courses in advance of 9, with the approval of the Chairman of the Department. Courses prerequisite to these must be taken, but cannot be counted in reckoning the eight required majors.

Chemistry courses given in the Departments of Geology and Home Economics may be included in these eight majors.

The eighth major of graduate work will be devoted to specific preparation (in residence) for the dissertation, either in the laboratory (research) or in the library (historical work), under the direction of some instructor chosen by the candidate.

[1] Course 35 will be omitted when courses 30–31 have included laboratory work.

THE DEGREE OF BACHELOR OF SCIENCE

Chemistry may be taken as a major subject to fulfil the requirement for a principal sequence or as a minor subject to fulfil the requirement for a secondary sequence.

I. PRINCIPAL SEQUENCES

1) Course 2, 3 (or 2S, 3S), 4, 6, 7, 8, 60 (or 61 or 62), and any other two courses in the Department except 1. If courses 33 and 34 or courses 30 and 31 be taken, course 4 is not required.

2) Combination with other science departments: By dropping the necessary majors from the latter portion of sequence 1) above, nine-major sequences may be offered involving the following courses: (1) three majors in College Physics, i.e., 3, 4, 5, but not 1, 2, preceding or accompanying 6 Chemistry courses enumerated in 1) above; (2) one to three majors in Geology selected from Geology 2, 3, 11, 12, 40–45, 50, 52, 53, when these courses follow Chemistry courses 2, 3 (or 2S, 3S), and 6; (3) two majors of Physiological Chemistry provided they are taken after courses 2, 3, (2S, 3S), 4, and 6 in Chemistry; (4) two majors in Chemistry of Foods and Dietetics, provided these courses follow 2, 3, (2S, 3S), 4, and 6 in Chemistry.

II. SECONDARY SEQUENCES

a) For students specializing in Physics: courses 2, 3, 6, 7, 8, and one major from courses 60, 61, 62.

b) For students specializing in Biological Science: courses 2, 3, 4, 6, 8, and one major from courses 60, 61, 62. If possible course 7 should also be taken.

c) For students specializing in Geology: courses 2, 3, 6, 7, 8, 9; the Department strongly advises courses 10, 14, and one major from courses 60, 61, 62.

SPECIAL STUDENTS

Special or unclassified students, not candidates for a degree, will be received, but in every case they will be required to give evidence, satisfactory to the instructors, that their previous training has been sufficient to enable them to derive full profit from the courses they propose to take.

PREPARATION FOR PROFESSIONAL WORK

I. PREPARATION FOR TEACHING

1. *University and College Positions.*—*a*) For recommendations for major appointments in the larger universities and colleges only students who have taken the degree of Doctor of Philosophy will be considered to have had an adequate preparation. *b*) For recommendations for chairs in Chemistry in smaller colleges, at least the preparation demanded for the Master's degree will be required. *c*) For recommendations for minor appointments in universities and colleges the work represented by the principal sequence of 9 majors in Chemistry required for the Bachelor's degree, supplemented by from three to eight majors of advanced work in Chemistry, will be considered an adequate preparation.

2. *Secondary Schools.*—The work represented by the principal sequence of 9 majors in Chemistry, required for the Bachelor's degree, is at present considered preparation for teaching in secondary schools. Some work in the College

of Education is recommended. Men will find it advisable to be prepared also to teach Physics, Mathematics, or Geology. Women will find it wiser to combine Chemistry with Physics, Physiography, Physiology, Botany, or Zoölogy.

II. PREPARATION FOR TECHNICAL WORK

1. Thorough scientific training in all branches of chemistry required for the Doctor's degree forms the best preparation for a career as a chemical expert in any branch of chemical industry. With this preparation, the principles and details of technical processes are quickly grasped, advances in industrial processes are intelligently followed, and newly discovered principles are readily applied.

All the more important requests received from technical establishments specify a doctorate of philosophy, with its training to do research work as a fundamental requirement.

2. Students who have taken from ten to fifteen majors of work in the Department are able to fill satisfactorily positions as assistants in technical and analytical laboratories and, after some practical experience, to advance to positions of independent responsibility. Students should take courses 1 to 10, inclusive, two majors in courses 13–19, and course 60 or 61. If the student's work is primarily in Organic Chemistry, he should take, if possible, two or three courses selected from 30–32 and 35–37; if his work is in Inorganic Chemistry primarily, he should take courses 50–52. Students taking the fuller preparation outlined are given the preference in answering requests received by the Department; but students with less complete training are also sought by technical firms for minor positions.

Work in Physics should supplement the work in Chemistry and a knowledge of Bacteriology is often most helpful.

3. The Department gives, with other departments (notably Physics and Mathematics) of the University, and the Department of Manual Training of the University High School, the equivalent of three years of a four years' course in Chemical Engineering. Students are able to take a large part of this work in the purely scientific fundamental branches, while they are candidates for a Bachelor's degree.

III. PREPARATION FOR GOVERNMENT WORK

1. For the more important government positions in Chemistry, the doctorate of philosophy is demanded as an essential condition for candidacy.

2. For minor positions (e.g., Junior Chemist in the United States service) the Bachelor's degree is considered sufficient. The principal sequence in Chemistry, required for the degree, should be supplemented by *advanced* work in two or three branches of Chemistry (Inorganic, Organic, Physical, Analytical). If possible, the full 15 majors allowed by the University rules should be taken in the Department besides work in Elementary Physics, German and French; a knowledge of Bacteriology is also helpful.

The Department does not pledge itself to secure positions for those who have carried out any one of the above recommended sets of courses; but, as a matter of fact, competent students find suitable places quickly, and in the past the demand for chemists has far exceeded the supply.

CHEMICAL SOCIETIES

The Kent Chemical Society is a club of students open to all those who have had six majors of Chemistry. The Society meets biweekly to listen to papers by members and others.

The Chicago Section of the American Chemical Society holds monthly meetings (except in summer) which the students of the University are welcome to attend. Membership in the Society is open to advanced students at special rates.

LABORATORY FEE

There is a laboratory fee of $5.00 per major for all courses involving laboratory work in the Department of Chemistry. A deposit of $5.00 for breakage is also required of each student.

COURSES OF INSTRUCTION

NOTE.—After course 9, the courses are arranged in groups according to subjects: courses 10–19 include courses in Analytical Chemistry, 30–49 in Organic Chemistry, 50–59 in Inorganic Chemistry, 60–79 in Physical Chemistry and Radioactivity; 80–89 are general in nature, and 90–100 are research courses. Nos. 10–19, 30–34, 40–43, 60, 61, 62, and 68–71 are open to, and suitable for, Senior College students.

I. PRIMARILY FOR THE JUNIOR COLLEGES

1. Elementary General Chemistry: Inorganic I.[1]—Prerequisite: preparatory Physics. DM. Summer, First Term. Classroom, 6 hours a week; laboratory, 12 hours a week; DR. STEWART. Mj. Autumn. Classroom, 3 hours a week; laboratory, 6 hours a week; PROFESSOR MCCOY AND ———.

2. General Chemistry: Inorganic II (continuation of course 1).—Prerequisite: course 1. DM. Summer, Second Term, DR. STEWART. Mj. Winter, PROFESSOR MCCOY AND ———.

NOTE.—Course 2, Winter Quarter, is a continuation of course 1, but may be entered by those having credit for admission Chemistry.

3. General Chemistry: Inorganic III (continuation of course 2).—Prerequisite: course 2. Mj. Spring, ———.

NOTE.—Courses 1, 2, and 3 are consecutive courses. Separate credit is given for each, but students are advised not to take one course only. The aim of these courses is to give a definite idea of the fundamental principles of chemistry, and not to overburden the student with a mass of unconnected facts. The conception of chemical equilibrium and the modern theory of solutions are freely used. The lectures will be experimental to a considerable extent. The courses are designed to meet the wants not only of those who wish to go deeper into chemistry, but of all who wish to study the science as part of a liberal education. The lectures and classroom work of 1, 2, and 3 may be taken by graduate students without the laboratory work or laboratory fee.

2S. General Chemistry: Inorganic (first course).—For students who have had preparatory Chemistry. Prerequisite: preparatory Chemistry and preparatory Physics, one unit each. DM. Summer, First Term. Classroom, 6 hours a week; laboratory, 12 hours a week, ASSISTANT PROFESSOR SCHLESINGER. Mj. Autumn. Classroom, 3 hours a week; laboratory, 6 hours a week, PROFESSOR HARKINS AND MR. TURNER.

3S. General Chemistry: Inorganic (continuation of course 2S).—DM. Summer, Second Term, ASSISTANT PROFESSOR SCHLESINGER; Mj. Winter, PROFESSOR HARKINS AND MR. TURNER.

NOTE.—Whenever, in exceptional cases, the preparation of a student in 2 or 2S justifies it, Qualitative Analysis may be substituted for 3 or 3S.

4. Elementary Organic Chemistry.—Prerequisite: course 3 or 3S. Classroom, 3 hours a week; laboratory, 6 hours a week; Mj. Autumn, DR. GLATTFELD; Spring, ———.

[1] Full credit only if taken as one of the first eighteen majors.

II. PRIMARILY FOR THE SENIOR COLLEGES

6. Qualitative Analysis (introductory course).—The lectures deal with the Chemistry of the analytical reactions, and special attention is given to the development and application of the laws of equilibrium and solutions. This course is, in an important sense, one in advanced General Chemistry. Classroom, 2 hours a week; laboratory, 8 or 16 hours a week. Prerequisite: course 3 or 3S. Mj. Summer and Winter, Dr. Terry; Autumn and Spring, Assistant Professor Schlesinger.

7. Qualitative Analysis (continuation of course 6).—Mj. or DM. Summer and Winter, Dr. Terry; Autumn and Spring, Assistant Professor Schlesinger.

Note.—Courses 6, 7, and 10 form a continuous course, which may be begun in any quarter. The aim of courses 6, 7, and 10 will be to train the student to do intelligent analytical work, based on a knowledge of the scientific principles of the subject, and to apply and amplify his knowledge of General and Physical Chemistry.

8. Quantitative Analysis (introductory course).—Chiefly laboratory work in gravimetric and volumetric analysis. Laboratory, 8 or 16 hours a week; lecture, 1 hour. Prerequisite: course 7. Medical students will be admitted to the course after having taken course 6. Mj. or DM. Summer, Dr. Wilson and Mr. Turner; Autumn and Winter, Dr. Stewart and Mr. Bunting; Spring, Dr. Glattfeld and Mr. Bunting.

8M. Quantitative Analysis.—A special course for premedical and medical students giving the elements of gravimetric and volumetric analysis. Prerequisite: course 6. Summer, either Term, Dr. Wilson; Autumn and Winter, ½Mj., Dr. Stewart; Spring, ½Mj., Dr. Glattfeld.

9. Quantitative Analysis (continuation of course 8).—Mj. or DM. Laboratory, 10 or 20 hours a week. Mj. Summer, Autumn, and Winter, Dr. Stewart and Mr. Bunting; Spring, Dr. Glattfeld.

Note.—Courses 8 and 9 form a continuous course which may be begun in any quarter.

III. PRIMARILY FOR THE GRADUATE SCHOOL

10. Advanced Qualitative Analysis (continuation of courses 6 and 7).—Open to Senior College students. Prerequisite: course 7. Mj. or DM. Laboratory, 10 or 20 hours a week. Summer and Winter, Dr. Terry; Autumn and Spring, Assistant Professor Schlesinger.

11. Advanced Quantitative Analysis (continuation of courses 8 and 9).—Open to Senior College students. Mj. or DM. Laboratory, 10 or 20 hours a week. Spring, Dr. Glattfeld.

12. Elementary Spectrum Analysis (Qualitative).—Emission (flame and electric spark) and absorption spectra of inorganic substances. Chiefly laboratory work. ½Mj. Winter, ———.

13–19. Special Methods in Quantitative Analysis.—Chiefly laboratory work. Open to Senior College students.

13. Electrolytic Methods	½Mj. or Mj.
14. Special Mineral Analysis	Mj.
15. Water Analysis	½Mj.
16. Gas Analysis	½Mj.
17. Organic Elementary Analysis	½Mj.
18. Iron and Steel Analysis	½Mj. or Mj.
19. Proximate Food Analysis	½Mj. or Mj.

Prerequisite: course 9. Domestic science and medical students will be admitted to courses 15 and 19 after having taken course 8. Summer, Dr. Wilson; Autumn and Winter, Dr. Stewart and Mr. Bunting; Spring, Dr. Glattfeld and Mr. Bunting.

20. Assaying.—Fire-assay of gold, silver, and lead ores. Prerequisite: course 9. [Not given in 1916–17.]

25. Toxicology.—½Mj. Autumn, Professor Haines and Assistant.

26. Poisons and Their Detection.—A conference and laboratory course. M. Spring, Second Term, PROFESSOR HAINES.

30. Organic Chemistry.—Lectures, 2 hours a week; laboratory, 6 hours a week. Prerequisite: Qualitative Analysis. Mj. Autumn, PROFESSOR STIEGLITZ.

31. Organic Chemistry (continuation of course 30).—Lectures, 3 hours a week; laboratory, 4 hours a week. Mj. Winter, PROFESSOR STIEGLITZ.

32. Organic Chemistry (continuation of course 31).—The Aromatic Series. Lectures, 2 hours a week; laboratory work, 4 hours a week. Mj. Spring, PROFESSOR STIEGLITZ.

NOTE.—Courses 30, 31, and 32 form a continuous course, covering the compounds of carbon, including the fatty and the aromatic series. The aim of the courses will be to take up thoroughly the simpler compounds, going with great detail into the chemical behavior, the characteristic reactions, and relationships of the different classes of organic compounds, and considering with great care the synthetic methods by which they can be obtained. Richter's, Perkins and Kipping's, or Bernthsen's *Organic Chemistry* is used as a reference book, but recent literature will be considered in detail. Students who have had adequate laboratory work in Organic Chemistry are admitted to the lectures without payment of a laboratory fee.

33. General Organic Chemistry.—Fatty and aromatic series. Lectures, 5 hours a week. Prerequisite: course 7. Mj. Summer, DR. GLATTFELD.

34. Elementary Organic Preparations.—Laboratory work, 10 hours a week. This course is arranged to accompany the lectures of course 33. It may be taken without the lectures by students who have had Organic Chemistry. Prerequisite: course 7. M. or Mj. Summer, DR. GLATTFELD.

35. Organic Preparations.—Laboratory work, 10 or 20 hours a week. Prerequisite: courses 7 and 9, Organic Chemistry (may be taken simultaneously with lectures on Organic Chemistry), and a reading knowledge of German. DM. Summer, First Term, PROFESSOR GOMBERG, Second Term, DR. GLATTFELD; Mj. Autumn, Winter, Spring, ASSISTANT PROFESSOR PICCARD.

36. Organic Preparations (continuation of course 35).—DM. Summer, First Term, PROFESSOR GORNBERG, Second Term, DR. GLATTFELD; Mj. Autumn, Winter, and Spring, ASSISTANT PROFESSOR PICCARD.

37. Organic Preparations (continuation of course 36).—DM. Summer, First Term, PROFESSOR GOMBERG, Second Term, DR. GLATTFELD; Mj. Autumn, Winter, and Spring, ASSISTANT PROFESSOR PICCARD.

NOTE.—Students who have taken the laboratory work of courses 30 and 31 or of course 34 will omit course 35 and go on with course 36.

41. The Aromatic Series.—Lectures, 2 hours a week. Prerequisite: Organic Chemistry. ½Mj. [Not given in 1917–18.]

42. The Carbohydrates and the Terpenes and Their Derivatives.—½Mj. PROFESSOR STIEGLITZ. [Not given in 1917–18.]

43. Organic Nitrogen Derivatives.—Uric-acid series, pyridine, quinone-imides, and phenazine compounds; a discussion of the alkaloids, ptomaines, and organic dye-stuffs. Prerequisite: course 31. ½Mj. PROFESSOR STIEGLITZ. [Not given in 1917–18.]

44. Physical Chemistry Applied to Organic Problems.—Lectures, 2 hours a week. Prerequisite: courses 31 and 60, 61, or 62. ½Mj. PROFESSOR STIEGLITZ. [Not given in 1917–18.]

45A. Selected Topics of Organic Chemistry.—Reversibility; tautomerism; stereoisomerism; organic dye-stuffs; application of the electron theory to organic compounds. Prerequisite: Organic Chemistry. ½Mj. PROFESSOR STIEGLITZ. [Not given in 1917–18.]

45B. Selected Topics of Organic Chemistry.—Prerequisite: Organic Chemistry. ½Mj. The subjects discussed will be selected from the field of chemistry of aromatic and cyclic compounds. Winter, PROFESSOR PICCARD.

46. Organic Dyes.—Prerequisite: The Aromatic Series. ½Mj. Winter, 1917, ASSISTANT PROFESSOR PICCARD.

47. Triaryl Methyls and Related Topics.—Prerequisite: The Aromatic Series. Mj. First Term, Summer Quarter, PROFESSOR GOMBERG.

50. Inorganic Preparations.—Laboratory work, 10 or 20 hours a week; classroom work, 2 hours a week. Prerequisite: course 9, and a reading knowledge of German. Mj. or DM. Summer and Winter, ASSISTANT PROFESSOR SCHLESINGER; Autumn, PROFESSOR HARKINS.

51. Inorganic Preparations (continuation of course 50).—Mj. or DM. Same schedule as course 50.

52. Inorganic Preparations (continuation of course 51).—Mj. or DM. Same schedule as course 50.

54A. Selected Topics in Inorganic Chemistry.—Dicussions of selected topics in inorganic chemistry such as peroxides and related salts, complex salts, hydrates, molecular compounds, iso- and heteropoly acids, Werner's theory, allotrophy, etc. Lectures only. ½Mj. ASSISTANT PROFESSOR SCHLESINGER. [Not given in 1917–18.]

54B. Selected Topics in Inorganic Chemistry.—Active hydrogen, nitrogen, oxygen, and chlorine; the passive state; Werner's theory, etc. ½Mj. Summer, ASSISTANT PROFESSOR SCHLESINGER.

55. Advanced General Chemistry.—Discussions bearing chiefly upon the work of courses 50, 51, and 52, and relating to such subjects as temperature measurement, crystal form and habit, isomorphism, solid solution, double salts, thermal analysis, alloys, transition temperatures, colloids, etc. This course is intended to supplement the work of the courses in inorganic preparations but can be taken independently. Prerequisite: same as for course 50. Lectures only. ½Mj. ASSISTANT PROFESSOR SCHLESINGER.

56. Special Topics in Inorganic Chemistry.—The subjects studied are the valence relations of the elements and the properties of the elements in selected groups of the periodic system. In 1915–16 the helium, the iron, and the rare earth groups were considered. ½Mj. PROFESSOR HARKINS. [Not given in 1916–17.]

57. The Periodic System and the Interrelations of the Elements.—Lectures, ½Mj. PROFESSOR HARKINS. [Not given in 1917–18.]

58. The Constitution of Liquids and Solids; Surface Tension and Colloids. Lectures. ½Mj. Summer, PROFESSOR HARKINS.

60. Elementary Physical Chemistry I.—Lectures, 2 hours a week; laboratory work, 8 hours a week. Lectures on laws of gases, atomic theory, kinetic theory, optical activity, phase rule, and related topics. Laboratory work on the determination of vapor-densities, molecular weights by freezing- and boiling-point methods, degrees of ionization by conductivity method, transference numbers, optical activity, and reaction velocity. Prerequisite: Physics 1 and Chemistry 8. Mj. Winter, ASSISTANT PROFESSOR SCHLESINGER.

61. Elementary Physical Chemistry II.—Lectures, 2 hours a week; laboratory work, 8 hours a week. Lectures on laws of solution, ionic theory, electro-chemistry, reaction velocity, chemical equilibrium, and related topics. Laboratory work; continuation of course 60. Mj. Spring, 1917, First Term, PROFESSOR ROSANOFF, Second Term, PROFESSOR HARKINS; Spring, 1918, PROFESSOR HARKINS.

62. Elementary Physical Chemistry.—Selected topics from courses 60 and 61. Lectures, 2 hours a week; laboratory work, 8 hours a week. Mj. Summer, PROFESSOR HARKINS.

63. Physico-chemical Measurements I.—Laboratory course. Continuation of 61, including a large variety of typical determinations. Course 65 should accompany or precede this course. Prerequisite: Physics 3 and Chemistry 61. Mj. or DM. Summer, PROFESSOR HARKINS; Autumn and Winter, PROFESSOR MCCOY.

64. Physico-chemical Measurements II.—Laboratory course. Continuation of course 63. Mj. or DM. Summer, PROFESSOR HARKINS; Autumn and Winter, PROFESSOR MCCOY.

65A, B, C, D. Chemical Dynamics.—Four consecutive advanced courses based on *Nernst's Theoretical Chemistry*. Prerequisite: courses 60, 61, 63, and Calculus. ½Mj. each Quarter. 65C, Autumn; 65D, Winter, PROFESSOR MCCOY.

66. Selected Topics in Physical Chemistry.—This will be largely a course on the application of physical chemistry to definite problems. Lectures. ½Mj. Winter, ASSISTANT PROFESSOR SCHLESINGER.

68. Radioactivity and the Nature of Matter.—Lectures. Prerequisite: course 60. ½Mj. [Not given in 1917–18.]

69. Laboratory Course in Radioactivity.—To accompany or follow course 68. ½Mj. or Mj. Summer and Autumn, ———.

71. The Atomic Theory.—Prerequisite: Elementary Physical Chemistry. ½Mj. PROFESSOR MCCOY. [Not given in 1917–18.]

75. Theories of Solutions I.—½Mj. PROFESSOR HARKINS. [Not given in 1917–18.]

76. Theories of Solutions II.—½Mj. PROFESSOR HARKINS. [Not given in 1917–18.]

77. The Free Energy of Chemical Reactions.—Prerequisite: Physical Chemistry and Calculus. ½Mj. Spring, PROFESSOR HARKINS.

78. The Chemistry of Gas Reactions.—Prerequisite: Physical Chemistry and Calculus. ½Mj. PROFESSOR HARKINS. [Not given in 1916–17.]

82. Club Meetings.—Meetings of the Kent Chemical Society will be held twice a month. They may be attended by anyone interested. The subjects for the meetings will be announced at least one week in advance. Summer, Autumn, Winter, and Spring.

83. The Teaching of Chemistry.—A series of conferences. ½Mj. [Not given in 1917–18.]

85. The Chemistry and Preparation of Medicinal Drugs.—½Mj. Spring, PROFESSOR HAINES.

90–93. Research Work.—These courses will include from 30 to 40 hours a week of laboratory work, under the special direction of some one of the instructors in the Department. It is expected that research work for a Doctor's thesis will require 4–6 quarters (4–6 DMjs.). Before being admitted to research a candidate must satisfy the instructors of the Department that his previous training has been sufficient.

90. Research in Organic and Physico-organic Chemistry.—Mj. or DMj. Autumn, Winter, and Spring, PROFESSOR STIEGLITZ (with DR. TERRY AND DR. ———).

91. Research in Physical Chemistry and Radioactivity.—Mj. or DMj. Autumn, and Winter, PROFESSOR MCCOY.

92. Research in General and Physical Chemistry.—Mj. or DMj. Summer, Autumn, Winter, and Spring, PROFESSOR HARKINS.

93. Research in Inorganic and Physical Chemistry.—Mj. or DMj. Summer, Autumn, Winter, and Spring, ASSISTANT PROFESSOR SCHLESINGER.

94. Research in Organic Chemistry.—Mj. or DMj. Autumn, Winter and Spring, ASSISTANT PROFESSOR PICCARD.

95. Research in Organic Chemistry.—Summer, Autumn, and Spring, DR. GLATTFELD.

96. Independent Research.—Summer, Autumn, Winter, and Spring. Mj.

97. Masters' Theses in Qualitative Analysis.—Mj. Winter and Spring, DR. TERRY.

98. Masters' Theses in Organic Chemistry.—Mj. Summer, Autumn, and Spring, DR. GLATTFELD.

99. Masters' Thesis in Quantitative Analysis.—Mj. Summer, DR. WILSON; Autumn and Winter, DR. STEWART; Spring, DR. GLATTFELD.

100. Research in Mineralogical and Geological Chemistry.—Mj. Autumn, Winter, and Spring, ASSISTANT PROFESSOR BROKAW (Geology).

101. Research in the Chemistry of Food.—Mj. Summer, Autumn, and Winter, ASSISTANT PROFESSOR BLUNT (College of Education).

CHEMISTRY COURSES IN THE DEPARTMENT OF PHYSIOLOGICAL CHEMISTRY

(See the Biological Group Circular)

CHEMISTRY COURSES IN THE DEPARTMENT OF GEOLOGY

50. Industrial Geology.—A study of the more important industries in which raw materials of mineral origin are prepared for use. The course includes a brief treatment of the metallurgy of the common metals and a study of the manufacture of coke, cement, clay products, glass, petroleum products, etc. Field trips on Saturdays to plants in and near Chicago are supplemented by detailed reports on each plant. Expenses about $10.00. Classroom work 3 days a week. Prerequisite: Geology 2, 3, 5, or 12, and a working knowledge of Chemistry. Mj. Autumn, ASSISTANT PROFESSOR BROKAW. [Not given in 1917–18.]

51. Petroleum and Coal.—An advanced course on petroleum and coal. The course includes a critical study of (1) the modern theories of origin, (2) the location, stratigraphy, and structure of the important fields of the world, (3) the methods of prospecting and exploiting the deposits, and (4) technology of oil and coal. Prerequisites: Geology 16. Desirable antecedent, Organic Chemistry. Mj. Autumn, ASSISTANT PROFESSOR BROKAW.

52. Ore Deposits.—A discussion of the principles of ore deposition; the nature, distribution, and genesis of metalliferous ore deposits in the United States; a study of the relations of ore deposits to geological structure and of the changes which ore deposits undergo through processes conditioned by factors related to depth. The course includes laboratory work illustrating the uses of mine maps and the compilation of geologic cross-sections through mines. Prerequisite: Geology 12, 16, and 30, Chemistry 6, Mathematics 3. Desirable antecedents: Mathematics 5, Mechanical Drawing, and Geography 12. Mj. Winter, ASSISTANT PROFESSOR BROKAW.

53. Chemistry of Ore Deposits.—The course will include (1) a study of physical and chemical laws applied to geological problems, with special reference to the phenomena involved in the formation of ore deposits; (2) studies in paragenesis and the interpretation of paragenetic groups of minerals; (3) the study and critical interpretation of geologic and mining reports dealing with the origin of ore bodies. Prerequisite: Geology 40. Mj. Spring, ASSISTANT PROFESSOR BROKAW.

54. Field Work in Mining and Mining Geology.—Students in Mining Geology are advised to spend some of their summers in mining camps where they may find employment as miners, mine samplers, assayers, draughtsmen, surveyors, etc. For the sake of experience it is desirable that they serve in as many different capacities as practicable. In many mining camps opportunity is offered for a study of General Geology, ore deposits, mining machinery, metallurgical works, etc. Frequent communication with the instructor is required, and when the work and reports are sufficiently thorough, credit will be given. Prerequisite: course 40. Summer, ASSISTANT PROFESSOR BROKAW.

CHEMISTRY COURSES IN THE DEPARTMENT OF HOME ECONOMICS

36. Chemistry of Food.—Study of the chemistry of fats, carbohydrates, proteins, as food constituents, with special emphasis upon the composition and nutritive value of such foods as meat, flour, milk, butter, etc. The laboratory

is partly qualitative and partly quantitative. Prerequisite: Organic Chemistry. Laboratory fee, $3.00. Mj. Summer, Autumn, and Winter, ASSISTANT PROFESSOR BLUNT AND MISS MCKEE.

37. Chemistry of Food (continued).—A continuation of the work in course 36. The subject-matter may be adapted to the special needs of the students. Lecture and laboratory. For graduate or Senior College students. Prerequisite: Home Economics 36 or its equivalent. Laboratory fee, $3.00. Mj. Winter, ASSISTANT PROFESSOR BLUNT AND MISS MCKEE.

38A. Nutrition.—A study of the processes of digestion and metabolism, and the nutritive requirements of the body, giving a scientific basis for the work in dietaries. The laboratory work consists chiefly of experiments on digestion and of qualitative and quantitative urine analysis in connection with special diets. Students may follow this course by either 39A or 38B, or both. Prerequisite: Home Economics 36. Laboratory fee, $1.50. M. Summer, First and Second Terms; Winter, First Term, ASSISTANT PROFESSOR BLUNT AND MISS ELIZABETH MILLER.

38B. Nutrition (continued).—A continuation of 38A. The course may include some study of pathological conditions in metabolism and a feeding or metabolism experiment. Laboratory fee, $1.50. M. Summer, Second Term, and Winter, Second Term, ASSISTANT PROFESSOR BLUNT.

39A. Dietaries.—A study of the food requirements of individuals as modified by age, sex, activity, etc., with special consideration given to the food of school children and institutional groups. The theory of infant feeding is included. Prerequisite: Home Economics 3 or 5 and 38A. Laboratory fee, $2.50. M. Summer and Winter, Second Term, 10:30–12:30, MISS ELIZABETH W. MILLER.

40. Seminar in Nutrition.—Reading and discussion of some of the recent work on normal and abnormal nutrition. Prerequisite: Home Economics 38A and 39A or their equivalent. The consent of the instructor must be obtained before registering. M. Summer, Second Term; ½Mj. Winter, ASSISTANT PROFESSOR BLUNT AND MISS ELIZABETH W. MILLER.

DOCTORS OF PHILOSOPHY OF THE UNIVERSITY OF CHICAGO

MATHEMATICS

1896 Leonard Eugene Dickson, Professor of Mathematics, University of Chicago.
The Analytic Representation of Substitutions on a Power of a Prime Number of Letters with a Discussion of the Linear Group.

John Irwin Hutchinson, Professor of Mathematics, Cornell University. Ithaca, N.Y.
On the Reduction of Hyperelliptic Functions ($p=2$) to Elliptic Functions by a Transformation of the Second Degree.

1898 Herbert Ellsworth Slaught, Professor of Mathematics, University of Chicago.
The Cross-Ratio Group of 120 Quadratic Cremona Transformations of the Plane.

1899 John Anthony Miller, Professor of Mathematics and Astronomy, Swarthmore College, Swarthmore, Pa.
Concerning Certain Elliptic Modular Functions of Square Rank.

1900 Gilbert Ames Bliss, Professor of Mathematics, University of Chicago.
The Geodesic Lines on the Anchor Ring.

George Lincoln Brown, Professor of Mathematics, South Dakota Agricultural College, Brookings, S.D.
A Ternary Linear Substitution Group of Order 3·360.

William Gillespie, Professor of Mathematics, Princeton University, Princeton, N.J.
On the Reduction of Hyperelliptic Integrals ($p=3$) to Elliptic Integrals by Transformation of the Second and Third Degree.

Derrick Norman Lehmer, Associate Professor of Mathematics, University of California, Berkeley, Cal.
Asymptotic Evaluation of Certain Totient Sums.

John Hector McDonald, Assistant Professor of Mathematics, University of California, Berkeley, Cal.
On the System of a Binary Cubic and Quadratic and the Reduction of Hyperelliptic Integrals of Genus Two to Elliptic Integrals by a Transformation of the Fourth Order.

Ernest Brown Skinner, Assistant Professor of Mathematics, University of Wisconsin, Madison, Wis.
Ternary Monomial Substitution Groups of Finite Order with Determinant ± 1.

1901 William Findlay, Professor of Mathematics, McMaster University, Toronto, Ont.
The Sylow Subgroups of the Symmetric Group.

Thomas Milton Putnam, Associate Professor of Mathematics, University of California, Berkeley, Cal.
The Quaternary Linear Homogeneous Group and the Ternary Linear Fractional Group.

1903 Oswald Veblen, Professor of Mathematics, Princeton University, Princeton, N.J.
A System of Axioms for Geometry.

1904 William Henry Bussey, Associate Professor of Mathematics, University of Minnesota, Minneapolis, Minn.
Generational Relations for the Abstract Group Simply Isomorphic with the Group LF(2; p^n).

Herbert Edwin Jordan, Assistant Professor of Mathematics, University of Kansas, Lawrence, Kan.
Group Characters of Various Linear Groups.

Arthur Whipple Smith, Associate Professor of Mathematics, Colgate University, Hamilton, N.Y.
Symbolic Treatment of Differential Geometry.

1905 Thomas Emory McKinney, Professor of Mathematics and Astronomy, University of South Dakota, Vermilion, S.D.
Concerning a Certain Type of Continued Fractions Depending on a Variable Parameter.

Robert Lee Moore, Assistant Professor of Mathematics, University of Pennsylvania, Philadelphia, Pa.
Sets of Metrical Hypotheses for Geometry.

1906 William Raymond Longley, Assistant Professor of Mathematics, Yale University, New Haven, Conn.
A Class of Periodic Orbits of an Infinitesimal Body Subject to the Attraction of n Finite Bodies.

Arthur Ranum, Assistant Professor of Mathematics, Cornell University, Ithaca, N.Y.
The Group of Classes of Congruent Matrices with Application to the Group of Isomorphisms of Any Abelian Group.

Anthony Lispenard Underhill, Assistant Professor of Mathematics, University of Minnesota, Minneapolis, Minn.
Invariants under Point Transformations in the Calculus of Variations.

Buzz M. Walker, Professor of Mathematics and Director of School of Engineering, Mississippi Agricultural and Mechanical College, Agricultural College, Miss.
On the Resolution of Higher Singularities of Algebraic Curves into Ordinary Double Points.

1907 George David Birkhoff, Assistant Professor of Mathematics, Harvard University, Cambridge, Mass.
Asymptotic Properties of Certain Ordinary Differential Equations, with Applications to Boundary Value and Expansion Problems.

Robert Lacey Börger, Professor of Mathematics, Ohio University, Athens, Ohio.
On the Determination of Ternary Linear Groups in the Galois Field of Order p^2.

Louis Ingold, Assistant Professor of Mathematics, University of Missouri, Columbia, Mo.
Vector Interpretation of Symbolic Parameters.

Nels Johann Lennes, Professor of Mathematics, University of Montana, Missoula, Mont.
Curves in Non-metrical Analysis Situs with an Application in the Calculus of Variations.

Frederick William Owens, Assistant Professor of Mathematics, Cornell University, Ithaca, N.Y.
The Introduction of Ideal Elements and Construction of Projective n-space in Terms of a Planar System of Points.

Norman Richard Wilson, Professor of Mathematics, University of Manitoba, Winnipeg, Canada.
Isoperimetrical Problems Which Are Reducible to Non-isoperimetrical Problems.

1908 Mary Emily Sinclair, Associate Professor of Mathematics, Oberlin, College, Oberlin, Ohio.
On a Compound Discontinuous Solution Connected with the Surface of Revolution of Minimum Area.

1909 Thomas Buck, Instructor in Mathematics, University of California, Berkeley, Cal.
Oscillating Satellites near the Lagrangian Equilateral Triangular Points.

Arnold Dresden, Assistant Professor of Mathematics, University of Wisconsin, Madison, Wis.
The Second Derivatives of the Extremal-Integral.

Harris Franklin MacNeish, Instructor in Mathematics, DeWitt Clinton High School, New York, N.Y.
Linear Polars of the k-hedron in n-space.

1910 Richard Philip Baker, Assistant Professor of Mathematics, State University of Iowa, Iowa City, Ia.
The Problem of the Angle-Bisectors.

William Hunt Bates, Assistant Professor of Mathematics, Purdue University, Lafayette, Ind.
An Application of Symbolic Methods to the Treatment of Mean Curvatures in Hyper-Space.

Theophil Henry Hildebrandt, Assistant Professor of Mathematics, University of Michigan, Ann Arbor, Mich.
A Contribution to the Foundations of Fréchet's Calcul Fonctionnel.

Egbert J. Miles, Assistant Professor of Mathematics, Yale University, New Haven, Conn.
The Absolute Minimum of a Definite Integral in a Special Field.

Anna Johnson Pell, Assistant Professor of Mathematics, Mount Holyoke College, South Hadley, Mass.
I. Biorthogonal Systems of Functions. II. Application to the Theory of Integral Equations.

Arthur Dunn Pitcher, Professor of Mathematics, Western Reserve University, Cleveland, Ohio.
The Interrelation of Eight Fundamental Properties of Classes of Functions.

Marion Ballantyne White, Dean of Women and Professor of Mathematics, State Normal School, Ypsilanti, Mich.
The Dependence of the Focal Point on Curvature in Space Problems of the Calculus of Variations.

1911 Lloyd Lyne Dines, Professor of Mathematics, University of Saskatchewan, Saskatoon, Canada.
The Highest Common Factor of a System of Polynomials, with an Application to Implicit Functions.

Theodore Lindquist, Professor of Mathematics, State Normal School, Emporia, Kan.
Mathematics for Freshman Students of Engineering.

Ralph Eugene Root, Professor of Mathematics, U.S. Naval Academy, Annapolis, Md.
Interated Limits in General Analysis.

Albert Harris Wilson, Associate Professor of Mathematics, Haverford College, Haverford, Pa.
The Canonical Types of Nets of Quadratic Forms in the Galois Field of Order p^n.

1912 Edward Wilson Chittenden, Instructor in Mathematics, University of Illinois, Urbana, Ill.
Infinite Developments and the Composition Property $(K_{12}B_1)_*$ in General Analysis.

1912 Charles Albert Fischer, Instructor in Mathematics, Columbia University, New York, N.Y.
Some Contributions to the Theory of Functions of Lines.

Charles Thompson Sullivan, Assistant Professor of Mathematics, McGill University, Montreal, Canada.
Properties of Surfaces Whose Asymptotic Lines Belong to Linear Complexes.

1913 William Charles Krathwohl, Assistant Professor of Mathematics, Armour Institute of Technology, Chicago, Ill.
Modular Invariants of Two Pairs of Cogredient Variables.

Wilson Lee Miser, Assistant Professor of Mathematics, University of Arkansas, Fayetteville, Ark.
On Linear Homogeneous Differential Equations with Elliptic Function Coefficients.

Frank Marion Morrison, Associate Professor of Mathematics, University of Washington, Seattle, Wash.
On the Relation between Some Important Notions of Projective and Metrical Differential Geometry.

Elton James Moulton, Assistant Professor of Mathematics, Northwestern University, Evanston, Ill.
On Figures of Equilibrium of a Rotating Heterogeneous Fluid Body.

*Mildred Leonora Sanderson.
Formal Modular Invariants with an Application to Binary Modular Covariants.

1914 Myer Gropp Gaba, Instructor in Mathematics, Cornell University, Ithaca, N.Y.
A Set of Postulates for General Projective Geometry of n Dimensions.

Harold Reynolds Kingston, Instructor in Mathematics, University of Manitoba, Winnipeg, Canada.
Metric Properties of Nets of Plane Curves.

William Vernon Lovitt, Instructor in Mathematics, Purdue University, LaFayette, Ind.
A Type of Singular Points for a Transformation of Three Variables.

Forbes Bagley Wiley, Professor of Mathematics, Denison University, Granville, Ohio.
Proof of the Finiteness of Modular Covariants of a System of Binary Form of Cogredient Points.

1915 Allen Fuller Carpenter, Instructor in Mathematics, University of Washington, Seattle, Wash.
Ruled Surfaces Whose Flecnode Curves Have Plane Branches.

Charles Ross Dines, Instructor in Mathematics, Dartmouth College, Hanover, N.H.
Functions of Positive Type and Selected Topics in General Analysis.

Jasper Ole Hassler, Instructor in Mathematics, Englewood High School, Chicago, Ill.
Plane Nets Periodic of Period Three under the Laplace Transformation.

Olive Clio Hazlett, Associate in Mathematics, Bryn Mawr College, Bryn Mawr, Penn.
On the Classification and Invariantive Characterizations of Nilpotent Algebras.

Archibald Henderson, Professor of Mathematics, University of North Carolina, Chapel Hill, N.C.
The Twenty-seven Lines upon the Cubic Surface.

Alfred Lewis Nelson, Instructor in Mathematics, University of Michigan, Ann Arbor, Mich.
Plane Nets with Equal Laplace-Darboux Invariants.

*Deceased.

1915 Vincent Collins Poor, Instructor in Mathematics, University of Michigan, Ann Arbor, Mich.
A Certain Type of Exact Solution of the Equations of Motion of a Viscous Liquid.

Samuel Watson Reaves, Professor of Mathematics, University of Oklahoma, Norman, Okla.
Metric Properties of Flecnodes on Ruled Surfaces.

Mary Evelyn Wells, Instructor in Mathematics, Vassar College, Poughkeepsie, N.Y.
The Determination of all Inequalities of Certain Types in General Linear Integral Equation Theory.

Chester Henry Yeaton, Assistant Professor of Mathematics, Northwestern University, Evanston, Ill.
Surfaces Characterized by Certain Properties of Their Directrix Congruences.

1916 Arthur McCracken Harding, Associate Professor of Mathematics, University of Arkansas, Fayetteville, Ark.
On Certain Loci Projectively Connected with a Given Plane Curve.

William Leroy Hart, Benjamin Peirce Instructor in Mathematics, Harvard University, Cambridge, Mass.
Differential Equations and Implicit Functions in Infinitely Many Variables.

Gillie Aldah Larew, Adjunct-Professor of Mathematics, Randolph–Macon Woman's College, Lynchburg, Va.
Necessary Conditions for the Problem of Mayer in the Calculus of Variations.

Arthur Shepard Merrill, Assistant Professor of Mathematics, University of Montana, Missoula, Mont.
An Isoperimetric Problem with Variable End-Points.

Arthur Richard Schweitzer, Chicago, Ill.
Les Idées directrices de la logique génétique des mathématiques.

David Melville Smith, Assistant Professor of Mathematics, Georgia School of Technology, Atlanta, Ga.
Jacobi's Condition for the Problem of Lagrange in the Calculus of Variations.

Pauline Sperry, Assistant Professor of Mathematics, Smith College, Northampton, Mass.
Properties of a Certain Projectively Defined Two Parameter Family of Curves on a General Surface.

MATHEMATICAL ASTRONOMY

1900 Forest Ray Moulton, Professor of Astronomy, University of Chicago.
Periodic Oscillating Satellites.

1903 William Albert Hamilton, Professor of Astronomy, Beloit College, Beloit, Wis.
The True Radii of Convergence for Expansions as Power Series in the Time, in the Case of Parabolic Motion.

1904 Arthur Constant Lunn, Assistant Professor of Applied Mathematics, University of Chicago.
The Differential Equations of Dynamics.

1905 Delonzo Tate Wilson, Assistant Professor of Mathematics, Case School of Applied Science, Cleveland, Ohio.
Work on Minor Planets.

1906 Frank Loxley Griffin, Professor of Mathematics, Reed Institute, Portland, Ore.
Certain Periodic Orbits of k Finite Bodies Revolving about a Relatively Large Central Mass.

1908 William Duncan MacMillan, Assistant Professor of Astronomy, University of Chicago.
Periodic Orbits about an Oblate Spheroid.

1909 Herbert Earle Buchanan, Professor of Mathematics, University of Tennessee, Knoxville, Tenn.
Periodic Oscillations of Three Finite Masses about the Langrangian Circular Solutions.

1911 Daniel Buchanan, Assistant Professor of Mathematics, Queen's University, Kingston, Ontario.
A Class of Periodic Solutions of the Problem of Three Bodies, Two of Equal Mass, the Third Moving on a Straight Line.

1913 Lloyd Arthur Heber Warren, Assistant Professor of Mathematics, University of Manitoba, Winnipeg, Canada.
A Class of Asymptotic Orbits in the Problem of Three Bodies.

1915 John William Campbell, Lecturer in Mathematics, Wesley College, Winnipeg, Canada.
Periodic Solution of the Problem of Three Bodies in Three Dimensions.

Louis Allen Hopkins, Instructor in Mathematics, University of Michigan, Ann Arbor, Mich.
On the Theory of the Motion of the Small Planets with a Periodic Orbit for the Hilda Type.

PRACTICAL ASTRONOMY AND ASTROPHYSICS

1913 Curvin Henry Gingrich, Assistant Professor of Astronomy, Carleton College, Northfield, Minn.
A Determination of the Photographic Magnitudes of Comparison Stars in Certain Hagen Fields.

Oliver Justin Lee, Instructor in Practical Astronomy, Yerkes Observatory, Williams Bay, Wis.
The Spectroscopic System 9 Camelopardalis.

1914 Frank Craig Jordan, Assistant Professor of Astronomy, University of Pittsburgh.
The Color-Changes of Certain Variable Stars of Short Periods.

1915 Harlan True Stetson, Instructor, Students' Astronomical Laboratory, Harvard University, Cambridge, Mass.
On the Apparatus and on Methods for Thermoelectric Measurements in Photographic Photometry, with Application to the Determination of Magnitude, Spectral Intensities, and the Light Curves of Variable Stars.

PHYSICS

1897 Gordon Ferry Hull, Professor of Physics, Dartmouth College.
On the Use of the Interferometer in the Study of Electric Waves.

Isabel Stone, Principal of American School for Girls, Rome, Italy.
On the Electrical Resistance of Thin Films.

1898 Edwin Sheldon Johonnott, Associate Professor of Physics, Rose Polytechnic Institution.
Thickness of the Black Spot in Liquid Films.

1899 Henry Gordon Gale, Professor of Physics, University of Chicago.
On the Relation between Density and Index of Refraction of Air.

1900 Robert Francis Earhart, Professor of Physics, Ohio State University.
The Sparkling Potentials between Plates at Small Distances.

1901 Fritz Reichmann, Practical Physicist, Troy, N.Y.
The Capacities of Air Condensers for Very Small Distances between the Plates.

1902 Frank Baldwin Jewett, Chief Engineer, Western Electric Co., New York City, N.Y.
A New Method of Determining the Vapor-Density of Metallic Vapors.

1904 Thomas Eaton Doubt, Associate Professor of Physics, Armour Institute of Technology, Chicago, Ill.
The Effect of Intensity upon the Velocity of Light.

Fannie Cornelia Frisbee (Mrs. Frank B. Jewett), New York City, N.Y.
The Effects of Pressure on Magnetic Induction.

Thomas Carlyle Hebb, Professor of Physics, State Normal School, Marquette, Mich.
The Velocity of Sound.

1905 Frederic Lendhall Bishop, Professor of Physics, University of Pittsburgh, Pittsburgh, Pa.
The Thermal Conductivity of Lead.

Glenn Moody Hobbs, Secretary of the American School of Correspondence, Chicago, Ill.
The Relation between P.D. and Spark-Length for Small Values of the Latter.

Carleton John Lynde, Professor of Physics, MacDonald College, Quebec, Can.
The Effect of Pressure on Surface Tension.

1906 William Richard Blair, Director Government Observatory, Mt. Weather, Va.
The Change of Phase Due to the Passage of Electric Waves through Thin Films.

Lawrence Emery Gurney, Assistant Professor of Physics, University of the Philippines, Manila, P.I.
The Viscosity of Water at Low Rate of Shear.

1907 Oliver Charles Clifford, Associate Professor of Electrical Engineering, Armour Institute of Technology, Chicago, Ill.
Susceptibility of Copper and Tin and Their Alloys.

George Winchester, Professor of Physics, Washington and Jefferson College, Washington, Pa.
Discharge of Electricity from Metals under the Influence of Ultra-Violet Light.

1909 William Ross Ham, Professor of Physics, Pennsylvania State College, State College, Pa.
The Polarization of Primary X-Rays.

Charles Albert Proctor, Assistant Professor of Physics, Dartmouth College, Hanover, N.H.

The Variation of $\frac{e}{m}$ with Speed in the Case of Cathode Rays.

Newland Farnsworth Smith, Professor of Physics, Central College, Danville, Ky.
Effect of Tension on Thermal and Electrical Conductivity.

1910 Louis Begeman, Professor of Physics, Iowa State Teachers College.
The Determination of "E" by the Cloud Method.

J. Harry Clo, Professor of Physics, Tulane University, New Orleans, La.
The Effect of Temperature upon the Ionization of Gas.

Ansel Alphonso Knowlton, Professor of Physics, Reed College, Portland, Ore.
Preparation and Testing of Heusler Alloys.

John Mathias Kuehne, Associate Professor of Physics, University of Texas, Austin, Tex.
The Electrostatic Effect of a Changing Magnetic Field.

1910 James Remus Wright, Associate Professor of Physics, University of the Philippines, Manila, P.I.
Photo-electric Effects of Aluminum as a Function of the Wave-Length of the Incident Light.

1911 Harold De Forest Arnold, Research Laboratory, Bell Telephone Company, New York.
Limitations Imposed by Slip and Inertia Terms upon Stokes Law for the Motion of Spheres through Liquids.

*Edwin Sherwood Bishop, Instructor in Physics, University High School, University of Chicago.
A Determination of the Minimum Ionizing Kinetic Energy of an Electron in a Gas.

Harvey Fletcher, Professor of Physics, Brigham Young University.
A Verification of the Theory of Brownian Movements and a Direct Determination of the Value of Ne for Gaseous Ionization.

Harvey Brace Lemon, Instructor in Physics, University of Chicago.
The Influence of Temperature upon the Intensities of the Lines of the Hydrogen Spectrum.

Howard Wilson Moody, Professor of Physics, Mississippi Agricultural College, Agricultural College, Miss.
A Determination of the Ratio of the Specific Heats and the Specific Heat at Constant Pressure of Air and Carbon Dioxide.

1913 Lachlan Gilchrist, Instructor in Physics, University of Toronto.
An Absolute Determination of the Viscosity of Air.

Edward James Moore, Associate Professor of Physics, Oberlin College, Oberlin, Ohio.
Reaction Effects Produced by the Discharge of Electricity from Points in Gases and the Bearing of These Effects on the Theory of the Small Ion.

1914 Albert Edward Hennings, Assistant Professor of Physics, University of Saskatchewan, Saskatoon, Canada.
A Study of the Contact Potentials and Photo-electric Properties of Metals *in Vacuo*.

Verne Frank Swaim, Assistant Professor of Physics, Bradley Polytechnic Institute, Peoria, Ill.
The Pressure-Shift of Lines in the Spectrum of Zinc.

1915 William Henry Kadesch, Instructor in Physics, U.S. Naval Academy, Annapolis, Md.
The Energy of Photo-Electrons from Sodium and Potassium as a Function of the Frequency of the Incident Light.

John Yui-Bong Lee, 520 Alin Street, Oakland, Cal.
The Determination of "E" by the Small-Drop Method Using Solid Spheres.

Isaiah March Rapp, Instructor in Physics, University of Oklahoma, Norman, Okla.
The Flow of Air through Capillary Tubes.

Oscar William Silvey, Instructor in Physics, Purdue University, La Fayette, Ind.
A Comparison of the Fall of a Droplet in a Liquid and in a Gas.

1916 Arthur Jeffrey Dempster, Assistant in Physics, The University of Chicago, Chicago, Ill.

Ertle Leslie Harrington, Missouri State Normal College, Cape Girardeau, Mo.
A Redetermination of the Absolute Value of the Coefficient of Viscosity of Air.
The Properties of Slow Canal Rays.

* Deceased.

1916 Yoshio Ishida, Assistant in Physics, The University of Chicago, Chicago, Ill.
The Kinetic Theory of Rigid Molecules.

Leonard B. Loeb, The Bureau of Standards, Washington, D.C.
Mobility of Gaseous Ions in High Electric Fields.

Carl Danforth Miller, The Westinghouse Research Laboratory, Pittsburgh, Pa.
Absorption Coefficients of Soft X-Rays.

Benjamin Estill Shackelford, The Westinghouse Company, New York, N.Y.
Temperature and Blackening Effects in Helical Tungsten Filaments.

William Henry Souder, Assistant in Physics, University of Chicago, Chicago, Ill.
The Normal Photoelectric Effect of Lithium, Sodium, and Potassium as a Function of Wave-Lengths and Incidental Energy.

Walter Ticknor Whitney, Claremont, California.
The Pole Effect in a Calcium Arc.

CHEMISTRY

1894 Adolph Bernhard, State Normal School, La Crosse, Wis.
Ueber die Einführung von Acylen in den Benzoylessigather.

Warren Rufus Smith, Professor of Chemistry, Lewis Institute, Chicago, Ill.
On the Addition Products of the Aromatic Isocyanides.

1896 Bernard Conrad Hesse, Consulting Chemist, General Chemical Co., New York City.
On Malonic Nitrile and Some of Its Derivatives.

Samuel Ellis Swartz, Professor of Chemistry and Physics, Fairmount College, Wichita, Kan.
The Action of Sodium Ethylate on Amide Bromides.

1897 James Bert Garner, Research Chemist, Mellon Institute of Industrial Research, Pittsburgh, Pa.
Condensations with Benzoin by Means of Sodium Ethylate.

Lauder William Jones, Professor of Chemistry, University of Cincinnati.
On Salts of Nitroparaffine and Acylated Derivatives of Hydroxylamine.

1898 Frank Burnett Dains, Professor of Chemistry, University of Kansas, Lawrence, Kan.
On the Isourea Ethers and Other Derivatives of Ureas.

Otto Folin, Hamilton Kuhn Professor of Biological Chemistry, Harvard Medical School, Boston, Mass.
On Urethanes.

Elizabeth Jeffreys, Professor of Chemistry, Pritchett College, Glasgow, Mo.
On Undecylamine and Pentadecylamine and the Preparation of the Higher Amines of the Aliphatic Series.

Herbert Newby McCoy, Professor of Chemistry, University of Chicago.
On the Hydrochlorides of Carbo-phenylimido Derivatives.

1899 John Charles Hessler, Professor of Chemistry, James Millikin University, Decatur, Ill.
On Alkyl Malonic Nitriles and Their Derivatives.

William McPherson, Professor of Chemistry, Ohio State University, Columbus, Ohio.
On the Nature of the Oxyazo Compounds.

1899 James Harvey Ransom, Professor of General Chemistry, Purdue University, Lafayette, Ind.
On the Molecular Rearrangement of o-Aminophenylethyl Carbonate to o-Oxyphenylurethane.

1900 Henry Chalmers Biddle, Associate Professor of Chemistry, University of California.
Ueber Derivate des Isuretins, der Formhydroxamsäure und ihre Beziehungen zur Knallsäure.

1901 Ralph Harper McKee, Director of Research Laboratory, Tennessee Copper Co., Ridgeway, N.J.
On the Oxygen Ethers of the Ureas: Methyl- and Ethylisourea.

1902 Solomon Farley Acree, Chief, Section of Derived Products, United States Forestry Products Laboratory, and Professor of Chemistry of Forest Products, University of Wisconsin, Madison, Wis.
On Sodium Phenyl and the Action of Sodium on Ketones.

Wallace Appleton Beatty, New York, N. Y.
The Action of Carbon Monoxide on Sodium Alcoholates Alone and in the Presence of Salts of Fatty Acids.

Eugene Paul Schoch, Professor of Chemistry, University of Texas, Austin, Tex.
The Red and the Yellow Mercuric Oxides and the Mercuric Oxychlorides.

Edwin Emery Slosson, Literary Editor of *The Independent*, New York City.
On Acylhalogenamine Derivatives and the Beckmann Rearrangement.

1903 Henry Tabor Upson, President and Treasurer, Pease Oil Co., Buffalo, N.Y.
The Molecular Rearrangement of Aminophenylalkyl Carbonates.

1904 Maxwell Adams, Professor of Chemistry, University of Nevada, Reno, Nev.
On Some Hydroxylamine Compounds.

Raymond Foss Bacon, Director of the Mellon Institute of Industrial Research, University of Pittsburgh, Pittsburgh, Pa.
On the Reactions of Sodium Benzhydrol.

William McAfee Bruce, Manager, Eastern Arkansas Demonstration Farm, Blackton, Ark.
On the Oxygen Ethers of Urea.

Nellie Esther Goldthwaite, Assistant Professor of Household Science, University of Illinois, Champaign, Ill.
On Substituted Benzhydrol Derivatives and Bromcyanacetic Ether.

Oswin W. Willcox, Chief Chemist and Superintendent, Aetna Explosives Co., Mount Union, Pa.
On the Reactions of Ethyl Chlorsulphonate.

1905 William Lloyd Evans, Professor of Chemistry, Ohio State University, Columbus, Ohio.
On the Behavior of Benzoyl Carbinol toward Alkalies and Oxidizing Agents.

William McCracken, Professor of Natural Sciences, State Normal School, Kalamazoo, Mich.
Studies in Catalysis. V. The Catalysis of Imidoesters.

Hermann Schlesinger, Assistant Professor of Chemistry, University of Chicago.
Studies in Catalysis. VI. The Catalysis of Imidoesters.

1906 Roy Hutchinson Brownlee, Director, American Carbo-Hydrogen Products Co., Pittsburgh, Pa.
On Precipitated Sulphur.

1906 Charles M. Carson, Professor of Chemistry, Houghton School of Mines, Houghton, Mich.
On Amorphous Sulphur: Further Study of the Two Forms of Liquid Sulphur as Dynamic Isomers.

Henry Max Goettsch, Assistant Professor of Technical Chemistry, University of Cincinnati, Cincinnati, Ohio.
The Absorption Coefficients of Uranium Compounds.

Willis Stose Hilpert, The Miner Laboratories, Chicago, Ill.
Stereoisomeric Chlorimido Acid Esters.

James Wright Lawrie, Chief Chemist and Manager for Jobbins & Co., Aurora, Ill.
The Chemistry of the Acetylidene Compounds.

Andrew Fridley McLeod, Instructor in Chemistry, Beloit College, Beloit, Wis.
On Aldol, Pentaerythrose, and the Action of Copper Acetate on the Hexoses.

1907 *Edith Ethel Barnard
The Catalysis of Imidoesters as Affected by the Presence of Non-Electrolytes and Electrolytes.

Katherine Blunt, Assistant Professor of Home Economics, University of Chicago.
The Formation of Amidines.

Willey Denis, Research Assistant, Harvard Medical School, Cambridge, Mass.
On the Behavior of Various Aldehydes, Ketones, and Alcohols toward Oxidizing Agents.

Robert Anderson Hall, Assistant Professor of Physiological Chemistry, University of Minnesota, Minneapolis, Minn.
The Action of Ammonia on Isourea Esters.

Louis Allen Higley, Professor of Chemistry, New Mexico College of Agriculture and Mechanical Arts, State College, N.M.
On the Behavior of Sodium and Sodium Alcoholates toward Various Esters.

William Horace Ross, Research Chemist, Bureau of Soils, Department of Agriculture, Washington, D.C.
On the Relation between the Radioactivity and the Composition of Thorium and Uranium Minerals.

Louis A. Test, Associate Professor of Chemistry, Iowa State College, Ames, Ia.
The Rearrangement of o-Amino Phenyl Esters.

1908 George Cromwell Ashman, Professor of Chemistry, Bradley Institute, Peoria, Ill.
Studies in Radioactivity.

1909 Ernest Anderson, Associate Professor of Chemistry, Massachusetts State Agricultural College, Amherst, Mass.
The Action of Fehling's Solution on *d*-Galactose.

William Weldon Hickman, Professor of Chemistry, Assuit College, Assuit, Egypt.
The Catalysis of Imidoesters.

Winford Lee Lewis, Assistant Professor of Chemistry, Northwestern University, Evanston, Ill.
The Action of Fehling's Solution on Maltose.

Peter Powell Peterson, Head of the Department of Soils in the College of Agriculture, University of Idaho, Moscow, Idaho.
Stereoisomerism of Chlorimido-Ketones.

* Deceased.

1909 Lemuel Charles Raiford, Professor of Chemistry, Oklahoma Agricultural and Mechanical College, Stillwater, Okla.
Chlorimido Quinones.

Herman Augustus Spoehr, Chemical Plant Physiologist, Carnegie Institution, Tucson, Ariz.
The Behavior of the Ordinary Hexoses toward Hydrogen Peroxide in the Presence of Alkaline Hydroxides as Well as of Various Iron Salts.

1910 Emma Perry Carr, Professor of Chemistry, Mount Holyoke College, Mt. Holyoke, Mass.
The Aliphatic Imidoesters.

Elbert Edwin Chandler, Professor of Chemistry, Occidental College, Los Angeles, Cal.
Ionization Constants of the Second Hydrogen Ion of Dibasic Acids.

Ira Harris Derby, Assistant Professor of Chemistry, University of Minnesota, Minneapolis, Minn.
Studies in Catalysis of Imidoesters, IV.

Stewart Joseph Lloyd, Professor of Chemistry and Metallurgy, University of Alabama, University, Ala.
Studies in Radioactivity.

Alan W. C. Menzies, Professor of Chemistry, Princeton University, Princeton, N.J.
Studies in Vapor-Pressure.

John Colin Moore, Instructor in Chemistry, Lake View High School, Chicago, Ill.
The Action of Water on Acyl Isoureas.

William Cabler Moore, Director of Research Laboratory, National Carbon Co., Cleveland, Ohio.
Studies in Organic Amalgams.

Fred Wilbert Upson, Professor of Chemistry, Agricultural College, University of Nebraska, Lincoln, Neb.
On the Action of Normal Barium Hydroxide on d. Glucose and d. Galactose.

1911 Thomas Bruce Freas, Associate Professor of Chemistry, Columbia University, New York, N.Y.
A Study of Thermostats.

John Foote Norton, Assistant Professor of the Chemistry of Sanitation, Massachusetts Institute of Technology, Boston, Mass.
Simultaneous Reactions in Amidine Formation.

Harlan Leo Trumbull, Assistant Professor of Chemistry, University of Washington, Seattle, Wash.
The Molecular Rearrangement of Acid Chloramides and the Ionization of Their Salts.

Leroy Samuel Weatherby, Professor of Chemistry, University of Southern California, Los Angeles, Cal.
The Salt-Effects of the Nitrates and Sulphonates in the Catalysis of Imidoesters.

Franklin Lorinzo West, Professor of Chemistry, Utah Agricultural College, Provo, Utah.
The Physical and Chemical Properties of Organic Amalgams.

1912 Paul David Potter, Chief Chemist, Sprague, Warner & Co., Chicago, Ill.
The Hydrates of Arsenic Pentoxide.

Charles Herman Viol, Chief Chemist, Standard Chemical Co., Pittsburgh, Pa.
The Chemical Properties and Relative Activities of the Radio-Products of Thorium.

1913 George Oliver Curme, Jr., Assistant Professor of Chemistry, University of Pittsburgh, and Research Chemist, Mellon Institute of Industrial Research, Pittsburgh, Pa.
The Thermal Decomposition of the Symmetrical Diaryl-Hydrazines.

John William Edward Glattfeld, Instructor in Chemistry, University of Chicago, Chicago, Ill.
The Oxidation of *d*-Glucose in Alkaline Solution by Air as Well as by Hydrogen Peroxide.

Paul Nicholas Leech, Research Chemist, American Medical Association.
The Molecular Rearrangement of Triaryl Methyl Hydroxylamines; a New Interpretation for the Rearrangement of Ketoximes.

Ethel Mary Terry, Instructor in Chemistry, University of Chicago.
The Velocity Coefficient of Saponification of Ethyl Acetate.

1914 Arthur Wesley Martin, Professor of Chemistry and Physics, University of Nanking, Nanking, China.
Studies on Solutions in Anhydrous Formic Acid.

Agnes Fay Morgan, Assistant Professor of the Chemistry of Nutrition, University of California, Berkeley, Cal.
I. Viscosities of Various Methyl and Ethyl Imidobenzoates and of the Sodium Salts of Para and Meta Nitrobenzoyl-chloroamides in Moderately Concentrated Aqueous Solutions. II. The Molecular Rearrangement of Some Triaryl Methylchloroamines.

Harry Morrill Paine, Research Chemist, Federal Dyestuff & Chemical Co., Kingsport, Tenn.
The Effects of Salts on the Solubility of Other Salts: 1. The Solubility Relations of a Very Soluble Bi-univalent Salt. 2. The Ionization of Bi-bivalent Salts.

Harley Martin Plum, Assistant Professor of Chemistry, Agricultural College, University of Nebraska, Lincoln, Neb.
The Extraction and Separation of the Radioactive Constituents of Carnotite.

Bert Allen Stagner, Professor of Chemistry, Fresno Collegiate High School, Fresno, Cal.
On the Molecular Rearrangements of Triarylmethyl Hydroxylamines.

Clare Chrisman Todd, Professor of Chemistry, Washington Agricultural College, Pullman, Wash.
The Action of Alkaline Hydrogen Peroxide on d. Galactose.

1915 Clifford Daniel Carpenter, Associate Professor of Chemistry, Teachers College, Columbia University, New York City.
The Addition Compounds of Organic Substances with Sulphuric Acid.

Oscar Fred Hedenburg, Research Chemist, Mellon Institute of Industrial Research, Pittsburgh, Pa.
On the Esters, as well as the Monomolecular B- and y-Lactones of d-Mannonic and d-Gluconic Acids; On Ortho Bis-d-Galactonic Acid, d-Galactonic y-Lactone and Its Mono-Hydrate.

Edmund Charles Humphery, Research Chemist, Federal Dyestuff and Chemical Co., Kingsport, Tenn.
Surface Tension at the Interface between Two Liquids.

Townes Randolph Leigh, Professor of Chemistry, Carleton College, Northfield, Minn.
On Chlorimido Esters and Chlorimido Benzil.

Edwin Daniel Leman, Research Chemist, Carnotite Reduction Co., Chicago, Ill.
The Relation between the Alpha-Ray Activities and Ranges of Radioactive Substances.

1915 Harold Stanard Adams, Research Biochemist, Squibbs & Co., New Brunswick, N.J.
Studies in Overvoltage.

Helen Tredway (Mrs. Evarts A. Graham) Mason City, Ia.
The Thermal Decomposition of Diaryl Hydrazines.

Ernest Dana Wilson, Research Chemist, Mellon Institute of Industrial Research, Pittsburgh, Pa.
The Structure of Complex Atoms.

1916 Groves Howard Cartledge, Professor of Chemistry and Physics, Presbyterian College of South Carolina, Clinton, S.C.
A Study of the Emanation Method of Determining Thorium.

Clyde Coleman, Research Chemist, Federal Dyestuff and Chemical Co., Kingsport, Tenn.
Further Studies on the Behavior of the Alkali Metal Formates in (Anhydrous) Formic Acid.

Ralph Edwin Hall, Research Chemist, Geo-physical Laboratory, Carnegie Institution, Washington, D.C.
The Periodic System and the Properties of the Elements. The Free Energy of Dilution. The Freezing-point Lowerings of some Salts of Various Types of Ionization and of Salt Mixtures.

Lawrence Melvin Henderson, Instructor in Chemistry, The University of Minnesota, Minneapolis, Minn.
The Ratio of Mesothorium to Thorium in Minerals.

Willard Allen Roberts, Instructor in Chemistry, Iowa State College, Ames, Iowa.
Studies on the Cobaltammines.

Stanley Davis Wilson, Assistant Professor of Chemistry, Rice Institute, Houston, Texas.
The Effect of Added Salts upon the Velocity of Saponification of Ethyl Acetate by Sodium Hydroxide.

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1918/19

The University of Chicago

FOUNDED BY JOHN D. ROCKEFELLER

CIRCULAR OF THE DEPARTMENTS OF

MATHEMATICS, ASTRONOMY AND ASTROPHYSICS, PHYSICS CHEMISTRY

1918

THE UNIVERSITY OF CHICAGO PRESS
CHICAGO, ILLINOIS

CALENDAR FOR THE YEAR 1918–19

1918

June 9	Sunday	Convocation Sunday
June 10	Monday	College Day
June 11	Tuesday	Summer Convocation
June 12	Wednesday	Examinations for the Spring Quarter
June 13	Thursday	
June 14	Friday	
June 14	Friday	Spring Quarter ends
June 15	Saturday	Registration for the Summer Quarter
June 17	*Monday*	*Summer Quarter begins*
June 17–22		Examinations of the College Entrance Examination Board
July 4	Thursday	Independence Day: a holiday
July 13	Saturday	Special Examinations for removal of deficiencies (work reported conditioned or incomplete) incurred during the last quarter of residence
July 23	Tuesday	Examinations for the First Term of the Summer Quarter
July 24	Wednesday	
July 24	Wednesday	First Term of the Summer Quarter ends
July 25	Thursday	Second Term of the Summer Quarter begins
Aug. 25	Sunday	Convocation Sunday
Aug. 29	Thursday	Examinations for the Second Term of the Summer Quarter
Aug. 30	Friday	
Aug. 30	Friday	Autumn Convocation Second Term of the Summer Quarter ends
Sept. 2–7		Examinations for Admission
Sept. 27	Friday	Registration for the Autumn Quarter, *of Undergraduates only*
Sept. 28	Saturday	
Sept. 30	Monday	Special Examinations for all students returning for the Autumn Quarter, who incurred deficiencies (work reported conditioned or incomplete) in the last quarter of residence
Sept. 30	Monday	Registration for the Autumn Quarter, *of students in all Divisions of the University*
Oct. 1	*Tuesday*	*Autumn Quarter begins: all classes meet*
Nov. 28	Thursday	Thanksgiving Day: a holiday
Dec. 15	Sunday	Convocation Sunday
Dec. 17	Tuesday	Winter Convocation
Dec. 18	Wednesday	Examinations for the Autumn Quarter
Dec. 19	Thursday	
Dec. 20	Friday	
Dec. 20	Friday	Autumn Quarter ends

1919

Jan. 2	*Thursday*	*Winter Quarter begins*
Jan. 25	Saturday	Special Examinations for removal of deficiencies (work reported conditioned or incomplete) incurred during the last quarter of residence
Feb. 12	Wednesday	Lincoln's Birthday: a holiday
Feb. 22	Saturday	Washington's Birthday: a holiday
Mar. 16	Sunday	Convocation Sunday
Mar. 18	Tuesday	Spring Convocation
Mar. 19	Wednesday	Examinations for the Winter Quarter
Mar. 20	Thursday	
Mar. 21	Friday	
Mar. 21	Friday	Winter Quarter ends
Mar. 22–30		Quarterly Recess
Mar. 31	*Monday*	*Spring Quarter begins*
April 26	Saturday	Special Examinations for removal of deficiencies (work reported conditioned or incomplete) incurred during the last quarter of residence
May 9–10		Annual Conference with Co-operating Schools
May 30	Friday	Memorial Day: a holiday
June 8	Sunday	Convocation Sunday
June 9	Monday	College Day
June 10	Tuesday	Summer Convocation
June 11	Wednesday	Examinations for the Spring Quarter
June 12	Thursday	
June 13	Friday	
June 13	Friday	Spring Quarter ends

OFFICERS OF ADMINISTRATION

HARRY PRATT JUDSON, President of the University, Harper Memorial Library, Room W11.

ERNEST DEWITT BURTON, Director of the University Libraries, Harper Memorial Library, Room M27.

WALTER A. PAYNE, University Recorder and University Examiner, Cobb Lecture Hall, Room 5A.

DAVID ALLAN ROBERTSON, Secretary to the President, Harper Memorial Library, Room W13.

JAMES ROWLAND ANGELL, Dean of the Faculties of Arts, Literature, and Science, Cobb Lecture Hall, Room 6A.

ALBION WOODBURY SMALL, Dean of the Graduate School of Arts and Literature, Cobb Lecture Hall, Room 6A.

ROLLIN D. SALISBURY, Dean of the Ogden Graduate School of Science, Cobb Lecture Hall, Room 6A.

MARION TALBOT, Dean of Women, Cobb Lecture Hall, Room 14A.

LEON CARROLL MARSHALL, Dean of the Senior Colleges, and Dean of the School of Commerce and Administration, Cobb Lecture Hall, Room 6B.

ROBERT MORSS LOVETT, Dean of the Junior Colleges, Cobb Lecture Hall, Room 9A.

‡HENRY GORDON GALE, Dean in the Colleges of Science, Cobb Lecture Hall, Room 7A. Major, United States Reserves, Signal Corps.

HORATIO HACKETT NEWMAN, Dean in the Colleges of Science, Cobb Lecture Hall, Room 10A.

PERCY HOLMES BOYNTON, JAMES WEBER LINN, Ellis Hall; FRANK JUSTUS MILLER, Lexington Hall; ELIZABETH WALLACE, Deans in Junior Colleges.

SOPHONISBA PRESTON BRECKINRIDGE, Assistant Dean of Women, Lexington Hall.

NATHANIEL BUTLER, Director of Co-operation with Secondary Schools; Dean of University College, Cobb Lecture Hall, Room 11A.

‡ On leave of absence.

GENERAL INFORMATION

The organization of the University includes: the Graduate School of Arts and Literature; the Ogden Graduate School of Science; the Colleges (Senior, last two years, and Junior, first two years) of Arts, Literature, and Science; the Divinity School, the Law School, Courses in Medicine, the School of Education, and the School of Commerce and Administration.

Faculty and equipment.—The faculty (exclusive of assistants) numbers three hundred and eighteen; the libraries contain 517,936 volumes and 200,000 pamphlets (estimated). The University owns nearly one hundred acres of land in Chicago and has forty buildings.

Location of the University.—The University grounds lie on both sides of the Midway Plaisance between Washington and Jackson parks, six miles south of the center of Chicago. Electric cars, elevated trains, and the Illinois Central suburban service reach all railway stations. Mail and baggage service is provided at the Information Office of the University.

The University year is divided into quarters: the Autumn (October, November, December); the Winter (January, February, March); the Spring (April, May, to the middle of June); the Summer (from the middle of June, July, August). For the year 1918–19 the exact dates for the opening of the four quarters are: Summer Quarter, June 17, 1918; Autumn Quarter, October 1, 1918; Winter Quarter, January 2, 1919; Spring Quarter, March 31, 1919. Students are admitted at the opening of each quarter; graduation exercises are held at the close of each quarter.

The unit of work and of credit is a *major*, i.e., a course of instruction involving four or five recitations or lecture hours per week for a full quarter, or double that number of hours for a term of six weeks. A *minor* is one-half a major. Normal work is three majors per quarter, or nine per year of three quarters.

Degrees.—The University confers in the Graduate Schools the degrees of Doctor of Philosophy and of Master of Arts and of Science; in the Colleges, the degrees of Bachelor of Arts, of Science, and of Philosophy; in the Divinity School, the degrees of Bachelor of Divinity, of Master of Arts, and of Doctor of Philosophy; in the Law School, the degrees of Doctor of Law and of Bachelor of Laws; in the School of Education, the degrees of Bachelor of Arts in Education, of Philosophy in Education, and of Science in Education; in the School of Commerce and Administration, the degree of Bachelor of Philosophy.

Fellowships, scholarships, student service, etc.—By virtue of endowments and special appropriations, fellowships and scholarships and service afford stipends or tuition to a number of able and deserving students. The University also maintains a bureau for securing outside employment.

Guests of the University.—Under certain conditions (see p. 7) Doctors of Philosophy of the University of Chicago and of other universities will be welcomed by the President as guests of the University.

FEES FOR MATRICULATION, TUITION, ETC.

A. *Matriculation fee.*—The Matriculation fee is $5.00, and is required of every student on entrance into the University.

B. *Tuition fee.*—1. The tuition fee for new students in the Colleges, the School of Commerce and Administration, and the School of Education, including also unclassified students, is:

One major, $25.00.
Two or three majors, $50.00.
Each additional major above three, $15.00.

For those students who have been registered in the above-mentioned groups prior to the Summer Quarter, 1917, the tuition fee will remain as heretofore, $40.00 for two or three majors, $20.00 for a single major, and for each additional major over three, $15.00.

2. *All tuition and laboratory fees are due on or before the first day of each quarter, and are payable without extra fee up to the end of the fifth day of the quarter. All fees are payable to the Cashier,* Press Building, Room 1.

C. *Fines, etc.*—For failure to pay tuition fees within the first five days of the quarter a fee of $5.00 is added to the bill.

D. *Laboratory fee.*—Students in most laboratory courses pay a laboratory fee of $5.00 a major (M. or DMj. courses will be charged in proportion). In the Departments of Home Economics and Household Art, Modeling and Ceramics, and Manual Training laboratory fees varying from $1.50 to $6.00 are charged for certain courses, depending on the nature of the course. Ten dollars ($10.00) is the maximum charge for laboratory work in any one department. In addition to the regular laboratory fee, students in Chemistry will procure a coupon ticket entitling them to $5.00 worth of laboratory material. Students doing laboratory work in the Departments of Zoölogy, Anatomy, Physiology, Botany, Pathology, and Hygiene and Bacteriology are required to purchase a laboratory supply and breakage ticket ($5.00 for a single course and $10.00 for more than one course in this group of departments) at the office of the Cashier and file the same at the laboratory supply store, Room 10, Botany Building. New tickets must be purchased at the opening of each quarter, and a refund of the unused balance on the old tickets can be obtained at that time.

E. *A small materials fee* is charged in certain courses in Political Economy and Sociology.

F. *Gymnasium locker fee.*—For the use of a locker in the dressing-room of the gymnasium a fee of $1.00 a quarter is charged. A small fee is also charged for the use of the tennis courts.

G. *Graduation fee.*—The general graduation fee, including diploma, is $10.00. The graduation fee for Doctors of Philosophy, including diploma and hood, is $15.00. In the case of students taking the certificate of a two years' course the charge is $5.00.

ROOMS, BOARD, AND GENERAL EXPENSES

There are ten residence halls in the University quadrangles. Two of these are reserved for the students of the Divinity School, and five are for women. A University House is organized in each hall; each House has a Head, appointed by the President of the University, and a House Committee, elected by the members; also a House Counselor, selected from the Faculties of the University by

the members of the House. The membership of the House is determined by election, and each House is self-governing under the general control of the University.

The cost of rooms in the halls is from $25.00 to $75.00 per quarter of twelve weeks. This includes heat, light, and care. Each hall for women has separate dining-hall and parlors. The cost of table board in these halls is $5.50 per week.

The increasing cost of foods and service has rendered it necessary to increase the rate of board from $4.50, the figure at which it has been maintained for several years, to $5.50 per week in the residence halls for women. It is doubtful whether the rate of $5.50 per week will fully recompense the University for the higher costs. It is hoped, however, that the price of foods will not go any higher, but rather will become lower, thus enabling the University to reduce the price as soon as circumstances warrant.

All applications for rooms, or for information concerning rooms and board, within the quadrangles should be made to the Cashier.

The table shown below will furnish an estimate of the annual expenses, exclusive of tuition and laboratory fees for thirty-six weeks, of a student in the University residing within the quadrangles.

	Lowest	Average	Liberal
Rent and care of room	$ 60.00	$105.00	$225.00
Board	162.00	198.00	240.00
Laundry	18.00	30.00	45.00
Textbooks and stationery	10.00	20.00	50.00
Total	$250.00	$353.00	$560.00

An opportunity to share in co-operative housekeeping and thereby to reduce living expenses somewhat is offered at Drexel House, which accommodates sixteen women who share in the preparation of meals and the care of the house. The cost of room rent for each student is $25.00 for the quarter, and the co-operative plan makes the cost of table board considerably less than is possible under other circumstances. Some experience in housekeeping and adaptability to group life are necessary. Correspondence with reference to rooms in Drexel House should be addressed to the Director of the Housing Bureau.

The University of Chicago maintains its Housing Bureau in order to assist its students in finding the best accommodations obtainable in the University neighborhood. All rooms listed have been inspected and certain standards are maintained. Rooms on small inclosed courts are not listed, and all householders registered must rent exclusively to men or exclusively to women. The use of a reception room at least two evenings a week must be provided for women students. Students are asked to co-operate by insisting on these requirements even if they do not engage their rooms through the Housing Bureau. Upon arrival at the University students should apply at once to the Housing Bureau for a list of rooms. Incoming students are especially cautioned against strangers who approach them at the station or on the streets and offer their services in securing rooms.

Most students off the quadrangles secure furnished rooms, which may be had at prices ranging from $30 to $60 a quarter, and take their meals at the University or at restaurants in the neighborhood. It is difficult to find good board by the week or month, and there are very few places where board and room are offered. As a result, it is customary to pay for each meal separately. Cafeteria service is provided at the University Commons—Ida Noyes Hall for women and Hutchinson Hall for men. Men occasionally find a small room, or a dark room, for less than $30 a quarter, but women usually have to pay $36 or more. Householders usually prefer men, hence the price level is higher for women. Not less than $4 a week should be allowed for table board, and one can seldom find a room with outside light, droplight, a study table, ample closet space, and a comfortable bed for less than $36 a quarter.

Desirable furnished rooms for light housekeeping are difficult to find. They range in price from $16 to $30 a month. In the University neighborhood there are very few two- or three-room apartments with private bath, and their rental unfurnished is from $30 a month up. The so-called kitchenettes in the vicinity of the University are small, usually dark, rooms with a kitchen table and gas plate, but never with running water. Rooms with kitchen privileges are to be had at the regular room rates with an additional charge of about $6 per quarter.

Furnished rooms or apartments of from four to ten rooms vary in price from $30 to $150 per month.

Lists of rooms may be obtained at the office, Room 1, Press Building, about one week before the opening of each quarter. Lists should be obtained in person at this office. Renting by mail is not satisfactory and students are advised against it.

DOCTORS OF PHILOSOPHY AS GUESTS OF THE UNIVERSITY

The President of the University, on recommendation of a Head of a Department, will welcome Doctors of Philosophy of the University of Chicago as well as of other universities as guests of the University, with the privilege of attending seminars and of carrying on research in the laboratories and libraries. There will be no charge except for laboratory supplies and a nominal laboratory fee where laboratory work is done. Arrangements should be made in advance with the President of the University.

FELLOWSHIPS AND SCHOLARSHIPS

The Trustees appropriate annually the amount of twenty-two thousand one hundred and forty dollars ($22,140) for Fellowships in the Graduate Schools of Arts, Literature, and Science. These Fellowships range in value from $120, the tuition fees of a graduate student for three quarters, to $520, that is, $400 in addition to the tuition fees for three quarters. A limited number of Scholarships, covering a part or all of the tuition fees for three quarters, are also awarded annually.

Candidates for these Fellowships and Scholarships should send to the Deans of the Graduate Schools a record of their previous work and distinctions, degrees, and past courses of study, with copies of their written or printed work in the field of the department in which application is made. Applications must be received at the Deans' offices *not later than March 1 of each year*, in order to be considered for the following year. Appointments will be made April 1.

Fellows may be called upon for assistance in teaching in the University or for kindred work; but in no case will they be expected or permitted to devote so much time to this work as to prevent the successful prosecution of their own work as students. Fellows will not engage in outside work for compensation unless by permission of the President. Except in rare cases students will not be appointed to Fellowships until they have done at least one year of graduate work.

In addition to the Scholarships mentioned above, one graduate Scholarship, yielding a sum sufficient to pay the annual tuition fees, is annually awarded to the best student in each department graduated from the University of Chicago during the preceding year.

A Scholarship yielding the amount of the tuition fees for three quarters is awarded annually in each department offering Junior College work to the student of highest rank in that department receiving the Associate's title during the preceding year.

Full particulars concerning higher degrees, Fellowships, Scholarships, and other matters of interest to graduate students will be found in the *Circular of Information* of the Colleges and Graduate Schools, which will be sent upon application.

AID TO STUDENTS

Besides Fellowships and Scholarships various kinds of assistance are offered to those who need help, under the following heads: Prizes, University Service, Loans by the Students' Fund Society, and Outside Employment. The position of the University in a large city brings the decided advantage of providing many opportunities for employment. Through the University Employment Bureau many students are able to secure all of the outside employment for which they have time. For further details applicants should send for the circular, *Assistance to Students at the University of Chicago.*

DEGREES

Graduate study may lead to a Master's or to a Doctor's degree under the conditions specified below:

I. THE MASTER'S DEGREE

Two degrees are conferred, viz., *Master of Arts* and *Master of Science.*

1. *Candidacy.*—Any member of the Graduate Schools who has been in attendance one quarter or more, and whose undergraduate course is equivalent to that required for a corresponding Bachelor's degree in the University of Chicago,[1] and whose thesis subject has been accepted by the department concerned, may, on recommendation by the department or departments in which he is working, be enrolled, by vote of the Faculties of the Graduate Schools, as a candidate for a Master's degree. Application for admission to candidacy must be made on the blank provided for the purpose. This blank must be obtained by the applicant at the Dean's office, and the application must be on file in that office at least two months before the degree is conferred.

[1] Attention is particularly called to the fact that the term "equivalent" in this connection refers to quantity only. It does not affect the question of the specific Master's degree (Arts or Science) to which a given student's work would lead. In case the candidate did not obtain his Bachelor's degree at the University of Chicago, he will present to the Examiner on blanks furnished for the purpose a detailed statement of his undergraduate work. The Examiner cannot always report upon these statements during the opening week of the quarter.

2. *Requirements.*—Students thus accepted as candidates will be given a Master's degree on fulfilment of the following requirements:

a) At least three quarters' residence at the University.

b) At least 8 majors of graduate work at the University of Chicago. These 8 majors need not be all in one department, but must be selected according to some rational plan approved by the Deans of the Graduate Schools at least six months before the degree is conferred. The individual courses must receive the approval of the heads of the departments concerned.

c) A satisfactory dissertation on a subject approved by one of the departments in which the work is done.[1] The subject of the dissertation must be approved by the Head of the Department at least three months before graduation, and the dissertation in complete form must be submitted to the Department at least four weeks before the degree is conferred. This period may be lengthened to six weeks at the option of any department.

d) The delivery of five printed or typewritten copies of the dissertation to the University Library at least one week before the Convocation at which the degree is to be conferred. One of the copies must be bound.

e) A satisfactory examination on the work taken for the degree.

f) No course completed with a grade below C will count toward the Master's degree.

II. THE DEGREE OF DOCTOR OF PHILOSOPHY

The degree of *Doctor of Philosophy* is given, not on the basis of the completion of a certain amount of time spent upon a specified program, but as the recognition and mark of high attainments and ability in the candidate's chosen province, shown, first, by the production of a dissertation evincing the power of independent investigation and forming an actual contribution to existing knowledge; and, secondly, by the passing of examinations covering the general field of the candidate's subjects, with more detail in the case of the principal subject, with less detail in the case of the secondary subject or subjects.

1. *Candidacy.*—Any member of the Graduate Schools who has been in attendance one quarter or more, whose undergraduate course is equivalent to that required for a Bachelor's degree in the University of Chicago,[2] whose thesis subject has been accepted by the principal department, and who has a reading knowledge of two modern languages other than English, may, on recommendation by the principal department in which he wishes to take his degree, be enrolled, by vote of the Faculties of the Graduate Schools, as a candidate for the Doctor's degree. The languages other than English must be languages which contain important critical literature of the subject in which the candidate's principal work is done. They must be selected with the approval of the department of principal work and of the Dean, and a reading knowledge of the languages must be certified by the appropriate departments not less than one academic year (9 months) before the degree is conferred. Application for admission to candidacy must be made on the blank provided for the purpose.

[1] In exceptional cases the Deans, upon the recommendation of the departments concerned, may accept an additional major in lieu of the dissertation.

[2] In case the candidate did not obtain his Bachelor's degree at the University of Chicago, he will present to the Examiner on blanks furnished for the purpose a detailed statement of his undergraduate work. The Examiner cannot always report upon these statements during the opening week of the quarter.

This blank must be obtained by the applicant at the Dean's office, and the application must be on file in that office before the close of the quarter preceding that in which the degree is conferred.

2. *Requirements.*—Students accepted as candidates will be given the Doctor's degree on the fulfilment of the following requirements:

a) At least three years of resident work in pursuance of an accepted course of study. The student may follow one of two plans. Plan I: The work offered in fulfilment of the requirements for the Ph.D. degree in any department is outlined by the Department and approved by the Dean, for each candidate, not later than the first quarter of his last year of residence work. The work required will include such courses in departments allied to that of principal work as may be deemed necessary by the principal department to obviate narrow specialization. The work is selected with regard to the needs of the individual student, with the double purpose (1) of giving him a knowledge of the relations of his principal subject to cognate branches of learning, and (2) of preparing him for productive scholarship. All courses offered in fulfilment of the requirement for the degree must be advanced courses, and a list of courses shall be submitted to the Faculties when the applicant is admitted to candidacy. Plan II: Under this plan the work offered must include one principal and either one or two secondary subjects. The amount of work required in the secondary subject or subjects is normally 9 majors. Candidates for the degree of Doctor of Philosophy may not, under this plan, take more than two-thirds of their work in one department, and may not take work which is to count toward the degree in more than three departments.

b) A satisfactory final examination upon the work done in preparation for the degree.

c) The presentation of a satisfactory dissertation upon a subject which has been approved by the Head of the Department in which the principal part of the candidate's work has been done.

d) A good command of literary expression and such knowledge of subjects considered fundamental as may be prescribed by the several departments.

3. *Dissertation.*—Each student is required to prepare a dissertation upon some topic connected with his principal subject. The dissertation must constitute an actual contribution to knowledge. Its subject must be submitted for approval to the Head of the Department at least twelve months before the date of the final examination. The dissertation itself must be submitted to the Head of the Department at least one month before the date of the final examination. This period may be lengthened to six weeks at the option of any department.

One week before the Convocation at which the degree is conferred a typewritten copy of the dissertation, together with a certificate signed by the Head or Acting Head of the Department that the copy, as submitted, is accepted for publication as the candidate's dissertation for the Doctor's degree, shall be filed in the office of the Deans of the Graduate Schools. Said copy may not be withdrawn from the office of the Deans of the Graduate Schools until the required one hundred copies are deposited in the Library.

The candidate shall deposit in the office of the Deans of the Graduate Schools a contract in legal form to the effect that he will furnish the General Library with one hundred copies (including two bound in half-roan) which shall fulfil in

format, cover, title-page, and stock all the University requirements. (See special circular entitled *Dissertation Regulations.*)

Any one of the following three methods may be followed:

a) A signed statement may be filed in the Graduate Office from a publishing agency approved as to its technical efficiency by the University of Chicago Press, and also as to its professional responsibility by the department concerned, that the dissertation has been received and accepted for publication.

The one hundred copies furnished to the General Library must be separate prints. They must contain no other material and must be put in covers (ninety-eight in paper covers and two in half-roan).

b) The candidate may deposit with the Business Office a legal financial guaranty sufficient to enable the University of Chicago Press to print the required one hundred copies, including the binding of two copies in half-roan. This guaranty shall mature at the expiration of two years from the date of the conferring of the degree.

c) The candidate may at his own cost secure publication of the dissertation in the form prescribed by the University, in which case the degree will be conferred only after the delivery of the required one hundred copies to the General Library.

Additional dissertation regulations:

d) Upon recommendation of a department and approval of the Dean of the Faculty immediately concerned, a form of the Doctor's dissertation briefer than that received in satisfaction of requirements for the degree may be accepted for publication. For instance, the alternative form of publication may be an account of the method pursued in the investigation, together with an abstract of the evidence used and a complete summary of the conclusions reached; or it may be a single chapter, provided the same represents a distinct unit of investigation.

e) In case the briefer form of the Doctor's dissertation is accepted for publication, five typewritten copies of the complete dissertation are required for deposit in the library in addition to the printed copies.

f) In case the course provided for in *d*) is adopted, arrangements for the same are made in the Dean's office before the expiration of the term fixed for publication.

g) Clauses *d*)–*f*) are held to modify other rules governing publication of dissertations in the one detail of providing for acceptance of a printed abbreviation in the place of the complete dissertation.

4. *Final examination.*—Plan I (see 2, *a*), p. 10): After admission to candidacy the student may present himself for examination as soon as he has fulfilled (1) the requirements of the department, and (2) the dissertation requirements (see 3, p. 10). The examination will be conducted by a committee consisting of members of the department in which the degree is to be taken, and a representative of some other department, appointed by the Deans of the Graduate Schools. The candidate is required to prepare a typewritten or printed brief of his work, including an analysis of the dissertation, and to file six copies of the same with his Dean for distribution to the committee one week before the time set for the examination. In the case of the examination in the secondary department, the statement should include the work in this department, and the statement for the final examination should include the work of both departments.

Plan II (see 2, *a*), p. 10): After admission to candidacy the student may present himself for examination in his secondary subject or subjects as soon as he has fulfilled the requirements of the department or departments concerned. He may present himself for the examination in his principal subject, or in both principal and secondary subjects if the examination in the latter has not been taken in advance, (1) as soon as he has fulfilled the requirements of the department or departments concerned, and (2) after he has made satisfactory arrangements as regards his dissertation. The examination will be conducted by a committee consisting of the members of the principal department concerned, an appointed representative of the secondary department, or a representative of each of them if there are two, of any other members of the secondary department who may choose to attend, and a member of some other department appointed by the Deans of the Graduate Schools. If the examination in the secondary subject or subjects is separated from the examination in the principal subject, the two may not be held in the same quarter nor within two months of each other.

5. *Non-resident work.*—After being admitted the student may be allowed to substitute non-resident work for resident work to a limited extent, under conditions to be arranged in consultation with the Dean and the heads of the departments concerned.

6. *Work done in other universities.*—Graduate work done in another university will be accepted as equivalent to resident work in the University of Chicago, provided the institution in which the work was done is of high standing, and adequate evidence is furnished that the work done there was satisfactorily performed. Graduate work done in other institutions cannot reduce the residence requirement at the University of Chicago to a period less than one year.[1]

[1] In order to avoid misunderstandings, candidates for higher degrees should consult their Deans concerning all technical requirements for such degrees before application is made for admission to candidacy. In all cases candidates should consult early with the heads of the departments of their major and minor subjects.

THE DEPARTMENT OF MATHEMATICS

OFFICERS OF INSTRUCTION

Eliakim Hastings Moore, Ph.D., LL.D., Sc.D., Math.D., Professor and Head of the Department of Mathematics.

Herbert Ellsworth Slaught, Ph.D., Sc.D., Professor of Mathematics.

George William Myers, Ph.D., Professor of the Teaching of Mathematics and Astronomy, the School of Education.

Leonard Eugene Dickson, Ph.D., Professor of Mathematics.

Gilbert Ames Bliss, Ph.D., Professor of Mathematics.

Ernest Julius Wilczynski, Ph.D., Professor of Mathematics.

Jacob William Albert Young, Ph.D., Associate Professor of the Pedagogy of Mathematics.

Arthur Constant Lunn, Ph.D., Associate Professor of Applied Mathematics.

Henry William Roever, Ph.D., Professor and Acting Head, Department of Mathematics, Washington University, St. Louis (Summer, 1918).

Roland George Dwight Richardson, Ph.D., Professor of Mathematics, Brown University (Summer, 1918).

FELLOWS, 1917–18

Cornelius Gouwens, A.M.
Ernest Preston Lane, A.M.
Minna Johanna Schick, A.M.
Webster Godman Simon, A.M.

GENERAL AIMS

The courses in Mathematics are intended for those studying mathematics as a part of a liberal education, for those expecting to apply mathematics in other sciences or in technology, for prospective teachers of mathematics or other sciences in secondary schools, colleges, and universities, and for workers and investigators in the most advanced fields of mathematics.

ARRANGEMENT OF WORK

The student will be aided in planning his work in Mathematics by the classification of courses (in the list given later) as primarily for the Junior College, the Senior College, or the Graduate School, and by the specific prerequisites named for each course. But the proper arrangement of work in mathematics is of such extreme importance that students are urged to consult instructors of the Department in planning their work. For graduate students a formal system of registration is in use which requires personal conference with the instructor of each course to be taken, and quarterly consultation with the departmental adviser selected by the student.

MATHEMATICAL SEQUENCES FOR UNDERGRADUATES

All courses offered by the Department of Mathematics or given numbers in its printed Announcements (called "mathematical majors" in what follows) may be used in mathematical sequences, except those whose numbers begin with 0.

Courses admissible for sequences in the Departments of Physics and Astronomy may also be used in mathematical sequences to an amount not greater than one-third of the total number of majors.

Principal sequences.—A principal sequence may consist of any nine admissible majors provided at least three mathematical majors are included whose numbers are higher than 17.

Secondary sequences.—A secondary sequence may consist of any six admissible majors provided at least one mathematical major is included whose number is higher than 14.

The following are given as illustrations of typical sequences:

PRINCIPAL SEQUENCES

a) Courses 1, 2, 3, 18, 19, 20, 47, 48, 49.
b) Courses 1, 2, 3, 18, 19, 23, 24, 31, 38.

SECONDARY SEQUENCES

a) Courses 1, 2, 3, 18, 19, 20.
b) Courses 1, 2, 3, 15, 23 or 29, 31 or 34.

MATHEMATICS AND ASTRONOMY

Principal Sequences

a) Courses 1, 2, 3, 18, 19, 20, Astronomy and Astrophysics 5, 6, 7.
b) Courses 1, 2, 3, 18, 19, Astronomy and Astrophysics 3A, 3B, 4.

Secondary Sequences

a) Courses 1, 2, 3, 15, Astronomy and Astrophysics 1, 7.
b) Courses 1, 2, 3, 15, Astronomy and Astrophysics 3A, 3B.

MATHEMATICS AND PHYSICS

Principal Sequences

a) Courses 1, 2, 3, 18, 19, 47, Physics 3, 4, 5, or 3S, 4S, 7.
b) Courses 1, 2, 3, 15, 23, 24, Physics 3, 4, 5, or 3S, 4S, 7.

Secondary Sequences

a) Courses 1, 2, 3, 15, Physics 3S, 4S.
b) Courses 1, 2, 3, 23, Physics 3S, 4S.

SEQUENCES FOR PROSPECTIVE TEACHERS

Principal Sequences

a) Courses 1, 2, 3, 18, 19, 23, 31, 37, 38.
b) Courses 1, 2, 6, 15, 26, 32, 34, 36 or 37, 39.

Secondary Sequences

Courses 1, 2, 3, 15, 23 or 31, 37 or 38.

STUDENTS IN GOVERNMENT SERVICE

Courses for students in government service.—The Department makes the following special provisions for the needs of students in government service during the war:

1. In case of need, the order of topics in certain courses will be rearranged so as to make it possible to take simultaneously courses that are customarily taken

in sequence; for example, trigonometry and plane analytics or calculus. Students desiring to make combinations of this sort should confer with the instructors of the courses in question before registering.

2. If desired by ten or more students, the Department will, whenever feasible, arrange a special course in mathematics for military men. Each such course will be planned to meet the needs of the group asking for it, military needs determining not only the topics to be taken up but also the aims and methods of instruction.

GROUPS OF COURSES

Certain Senior College and early graduate courses introductory to the higher mathematics may be grouped for reference as follows: (A) †Differential and integral calculus with applications (3Mj.); (B) †Solid analytics; selected topics in geometry; theory of equations; determinants and elementary invariants; limits and series; (C) †Analytic mechanics (2Mj.); vector analysis; celestial mechanics (2Mj); (D) †Advanced calculus, †differential equations, †theory of definite integrals, elliptic integrals, Fourier series and Bessel functions, elements of the theory of functions; (E) Synthetic projective geometry; analytic projective geometry; differential metric geometry; differential projective geometry; (F) Theory of numbers; theory of invariants; selected chapters of algebra; theory of substitutions with applications to algebraic equations.

NOTE.—The courses marked † are given annually; the other courses usually once in two years.

These courses and the special courses in the Higher Mathematics are intended to give the student a comprehensive view of modern mathematics, to develop him to scientific maturity, and to enable him to follow, without further guidance, the scientific movement of the day in mathematics, and, if possible, to take an active part in it by creative research.

The special and research courses vary from year to year. They may be classified, in general, as relating to (*a*) Algebra and Arithmetic; (*b*) Analysis; (*c*) Geometry; (*d*) Mechanics and Applied Mathematics; and (*e*) the Foundations and Interrelations of the Mathematical Disciplines as purely abstract deductive systems. Courses of type (*d*) are also offered by the Departments of Astronomy and Physics.

PREPARATION FOR TEACHING

Courses in the history and the teaching of Elementary Mathematics—Arithmetic, Algebra, Geometry, Trigonometry, Analytic Geometry, Calculus, Mechanics—are offered by this Department and the School of Education. These courses embody the conviction that elementary students need to have their mathematics made not easier but more perfectly intelligible and attractive. To this end it is believed that teachers should more generally appreciate and utilize in instruction the unity of mathematics, as made up of various closely interrelated parts, and the character of mathematics, as an ideal science developed by abstraction from various more concrete domains.

A) *Secondary-school positions.*—Students who expect to teach mathematics as a major subject in secondary schools should complete at least the following courses in their undergraduate career: (1) Courses in pure mathematics: Trigonometry, College Algebra, Plane Analytic Geometry, Differential and Integral

Calculus and Applications of Calculus, Theory of Equations, and the Synoptic course; (2) Courses in applied mathematics: Descriptive Astronomy, Mechanics, and General Physics; (3) The two courses, Principles of Education and Methods of Education, which may be taken either in the Junior College or in the Senior College; (4) Practice Teaching in Mathematics in the University High School, for which the foregoing courses in education are prerequisite; (5) A course in the Teaching of Secondary Mathematics and a course in the History of Secondary Mathematics.

B) *Minor collegiate positions.*—Those who look forward to teaching mathematics in normal schools and small colleges should as undergraduates complete at least the following courses: (1) The general courses in education and those in the history and teaching of mathematics mentioned in (3) and (5) above; (2) The content courses specified in (1) and (2) above, together with Advanced Calculus (3 majors).

Candidates for these positions should take at least one year of graduate work leading to the Master's degree in Mathematics and during this year should visit some of the college courses in Mathematics with the purpose of observing methods of teaching.

C) *University positions.*—Candidates for university positions should qualify for the Doctor's degree. Courses in the history of mathematics and in the principles and practice of education are strongly recommended.

HIGHER DEGREES

Master's degree.—Candidates for the Master's degree in Mathematics are expected, on the basis of a principal sequence of nine majors of undergraduate mathematics, to offer for examination eight approved courses of groups (A)–(E), including the elements of the theory of functions, and to present a satisfactory dissertation on an assigned topic closely related to the subject of one of the courses.

Degree of Doctor of Philosophy.—Candidates for the Doctor's degree with Mathematics as secondary subject are expected to offer for examination nine approved courses in advance of course 3.

Candidates for the Doctor's degree with Mathematics as principal subject are expected (1) to offer for examination the subjects covered by fifteen majors of initial courses of groups (B)–(F), including two of each of the types (*a*)–(*e*), and by a considerable body of special courses, in each case presumably most closely related to the subject of the doctoral dissertation, and (2) to present a dissertation, in finished form, embodying valuable results of mathematical inquiry. The subject of the dissertation may be a topic of pure or applied mathematics or of the history, philosophy, or pedagogy of mathematics.

MISCELLANEOUS INFORMATION

Clubs.—The Departmental Club meets regularly for the review of memoirs and books, and for the presentation of results of research. The club is conducted by the members of the Faculties of Mathematics and Mathematical Astronomy. Graduate students of the Departments are expected to attend and otherwise to participate in the meetings of the club.

The Junior Mathematical Club, with fortnightly meetings, is conducted by the graduate studentts of the Departments of Mathematics and of Astronomy and Astrophysics.

Library.—The library contains the more important works on mathematics (about 7,200 volumes) and has current issues and complete files of the leading periodicals.

Models.—The collection of models includes a set of Brill's models: plaster and thread models of quadric surfaces, plaster models of cubic and Kummer's quartic surfaces, models of cyclides and surfaces of constant positive and negative curvature, and thread models of three-dimensional projections of four-dimensional regular bodies.

Summer Quarter.—The courses of the Summer Quarter are planned with special reference to the needs of those who are able to spend only the summer in residence. The courses are arranged so as to enable the student to continue his work progressively in successive summers, and so that the courses of four consecutive summers give a wide view of modern mathematics. The student who is obliged to leave before the close of the Summer Quarter may usually arrange to complete his work by correspondence.

Scholarship examinations.—The competitive examinations for the Senior College Scholarship and for the Graduate Scholarship in Mathematics are held each Spring Quarter at times and places announced in the *Weekly Calendar*. Prospective candidates should confer with the Departmental Examiner in Mathematics. Files of papers set at previous Scholarship examinations are accessible in the Departmental Library. Candidates for the Senior College Scholarship will be examined on courses 1, 2, and 3; those for the Graduate Scholarship on courses 18, 19, 20, 23, 24, 31, 47, 48, and 49.

COURSES OF INSTRUCTION

I. JUNIOR COLLEGE COURSES

00. Advanced Algebra.[1]—A collegiate treatment of quadratic equations and other topics of the third semester of algebra of the secondary school. For students who offer only one unit of mathematics for entrance. Mj. Autumn, MR. ———.

01, 02. Plane Geometry I, II.[1]—A collegiate treatment of plane geometry for students who offer no geometry for entrance. Two consecutive majors. Winter and Spring, MR. ———.

1. Plane Trigonometry.—Mj. Summer, PROFESSOR ROEVER; Autumn, 2 sections, PROFESSOR SLAUGHT AND ASSOCIATE PROFESSOR LAVES; Winter, 2 sections, ASSOCIATE PROFESSOR YOUNG AND MR. ———; Spring, 2 sections, PROFESSOR SLAUGHT AND MR. ———.

2. College Algebra.—M. Summer, First Term, PROFESSOR MOORE; Mj. Autumn, PROFESSOR MOORE; Winter, MR. ———; Spring, ASSOCIATE PROFESSOR YOUNG.

3. Analytic Geometry.—Elements of plane analytics, including the geometry of the conic sections, with an introduction to solid analytics. Prerequisite: course 1. Mj. Summer, ASSOCIATE PROFESSOR YOUNG; Autumn, PROFESSOR DICKSON; Winter, PROFESSOR MOORE; Spring, PROFESSOR SLAUGHT.

[1] Limited-credit course: After a student has credit for 18 majors but less than 27, these courses will be credited at one-half major each; after he has credit for 27 majors they will not be credited at all.

7, 8, 9. Applied Mathematics I, II, III.—An intensive training course in mathematical methods for students who expect to undertake scientific work; in close connection with corresponding courses offered by the Departments of Physics and Chemistry. Numerical and algebraic computations, mensuration and trigonometry, graphical methods and the main notions of analytic geometry, together with the differential and integral calculus of a few elementary functions. Topics will be chosen with primary reference to their bearing on physics, chemistry, and engineering, and problems from those sources will constitute the bulk of the illustrative material used. Prerequisite: Satisfactory preparation in elementary algebra and geometry and previous or simultaneous work in physics. Three consecutive majors. Autumn, Winter, and Spring, ASSOCIATE PROFESSOR LUNN.

15. Introductory Calculus.[1]—The elementary fundamental principles, methods, and formulas of differential and integral calculus will be carefully studied in connection with simple problems of geometry and the physical sciences. This course is intended primarily for those who do not wish to take the longer course in Calculus (courses 18, 19, and 20). Prerequisite: course 1. Mj. Spring, ASSOCIATE PROFESSOR YOUNG. [Not given in 1919.]

II. SENIOR COLLEGE COURSES

18,[2] 19, 20. Calculus I, II, III.—A development of the three fundamental notions of the Calculus: the derivative, the anti-derivative, the definite integral, with especial emphasis on their geometric interpretations and their relations to problems in geometry, mechanics, and physics. Prerequisite: courses 1, 2, and 3. Three consecutive majors. Autumn, Winter, and Spring, 2 sections, PROFESSOR WILCZYNSKI.

18,[2] 19. Calculus I, II.—Prerequisite: courses 1, 2, and 3. Two consecutive majors. Winter and Spring, ASSOCIATE PROFESSOR YOUNG.

18. Calculus I: Differential Calculus.—A graphic study of rational algebraic functions and of certain simple irrational transcendental functions, yielding material for a geometric introduction to the fundamental notions and processes of the Calculus. Prerequisite: courses 1, 2, and 3. Mj. Summer, PROFESSOR RICHARDSON.

19. Calculus II: Integral Calculus.—A course aimed at a comprehension of the nature of integration and of its applications to geometry and physics; solution of numerous problems; use of table of integrals. Prerequisite: course 18. Mj. Summer, PROFESSOR SLAUGHT.

21. Advanced Calculus.—Selected topics in the Differential and Integral Calculus requiring more extensive and theoretic treatment than is given in courses 18 and 19: for example, development of the formulas for successive differentiation and the differentiation of implicit functions, Taylor's formula with applications, transformation of variables in different equations and multiple integrals, line integrals and partial integration of multiple integrals. Prerequisite: courses 18 and 19. Mj. Autumn. [Not given in 1918.]

22. Elementary Theory of Equations.—The course covers those sections of Dickson's *Elementary Theory of Equations* which are not marked by a dagger. Prerequisite: Differential Calculus. Mj. Winter, PROFESSOR DICKSON.

23. Solution of Numerical Equations.—Isolation of the real roots by graphic methods and by use of Sturm's functions; Newton's and Horner's methods of solution; algebraic solution of cubic and quartic equations. Text: Dickson's *Elementary Theory of Equations*. Prerequisite: Differential Calculus. M. Summer, First Term, PROFESSOR DICKSON.

[1] See footnote for course 18.

[2] If a student has credit for course 15, credit will be given for course 18 only in case the latter is completed with the standing of B – or better.

24. Determinants and Symmetric Functions.—With applications to systems of linear equations and the theory of elimination. Text and prerequisite as in course 23. Students may enter without course 23 if thoroughly familiar with college algebra. M. Summer, Second Term, PROFESSOR DICKSON.

28. Selected Topics in Mathematics.—Based on certain parts of the "Monographs on Topics of Modern Mathematics Relevant to the Elementary Field," edited by J. W. A. Young. Mj. [Not given in 1918–19.]

29. Synthetic Projective Geometry.—A development of projective geometry from the purely synthetic standpoint. Fundamental forms of the first and second orders; conic sections and surfaces of the second order; involution with applications; quadratic transformations, plane systems, point systems and space systems projectively related, with some study of space curves and of line geometry. [Not given in 1918–19.]

29, 30. Projective Geometry I, II.—The fundamental notions of projective geometry treated both analytically and synthetically. The method of abbreviated notation and homogeneous co-ordinates. Theory of determinants and their application to the geometry of two and three dimensions. Projective and dualistic transformations and the simpler Cremona transformations. Notions of group and invariant. Prerequisite: courses 1, 2, 3, 18, 19. Two consecutive majors. Winter and Spring, 1920, PROFESSOR WILCZYNSKI.

31. Solid Analytics.—This course may be taken simultaneously with course 18; it is an advisable antecedent of course 19. Prerequisite: courses 3 and 18. Mj. Spring, PROFESSOR DICKSON.

34. Limits and Series.—Definitions and fundamental properties of various types of limits. Prerequisite: Differential and Integral Calculus. Mj. Spring, PROFESSOR MOORE.

The Teaching of Elementary-School Mathematics (School of Education: Mathematics 1).—Mj. Winter, PROFESSOR MYERS.

The Teaching of Secondary Mathematics (School of Education: Mathematics 2).—Mj. Spring, PROFESSOR MYERS.

History of Mathematics (School of Education: Mathematics 5).—Mj. Winter, PROFESSOR MYERS.

37. Critical Review of Secondary Mathematics.—A brief survey of the subject-matter of Secondary Mathematics from the modern point of view, aiming both to organize the theory of the whole scientifically and to gather the products of this work for use in teaching. Primarily for teachers, actual and prospective, but open also to others. Mj. Summer, ASSOCIATE PROFESSOR YOUNG. [Not given in 1918.]

38. Synoptic Course in Advanced Mathematics.—A general historical and logical survey of a considerable portion of pure and applied mathematics. Prerequisite: courses 1, 2, and 3. Mj. PROFESSOR WILCZYNSKI. [Not given in 1918–19.]

Analytic Mechanics I, II. (Astronomy 5, 6).—An introductory course. Prerequisite: Mathematics 18, 19. 2Mjs. Autumn and Winter, ASSOCIATE PROFESSOR LAVES.

40. Topics of Geometry.—The topics will be selected from the following: foundations of geometry, nature and value of geometric reasoning, methods of solution of geometric problems, limits in geometry; anharmonic ratio, complete quadrilateral, polars, duality, modern geometry of the triangle, geometric conics, and others. There will be much work in actual solution of problems. Prerequisite: entrance plane geometry. Mj. (or M. either Term), Summer, ASSOCIATE PROFESSOR YOUNG.

41. Descriptive Geometry.—The graphical solution (with the instruments of the geometer) of the problems of space. The various methods of Monge, of free perspective, of contour lines, and of axonometry. Applications to the

solution of important geometrical problems in technology, architecture, crystallography, and spherical astronomy. The method of treatment aims to develop the geometric type of reasoning and to stimulate the power of space visualization. Prerequisites: Solid Geometry and Analytic Geometry essential, Calculus desirable. Three hours lecture, two hours laboratory, per week. Mj. (or M. First Term), Summer, PROFESSOR ROEVER.

47. Differential Equations.—A study of the more common types of ordinary differential equations, especially those of the first and second orders, with emphasis on geometrical interpretations and applications to geometry, elementary mechanics, and physics. Prerequisite: courses 18, 19, and preferably 20. Mj. Autumn, PROFESSOR SLAUGHT.

48. Elliptic Integrals.—A systematic development of the theory of indefinite integration, leading to elliptic integrals and the elements of elliptic functions, with attention to problems and applications. This course includes also an introduction to Fourier series. Prerequisite: courses 18, 19, 20, and preferably 46 or 47. Mj. PROFESSOR SLAUGHT. [Not given in 1918–19.]

49. Theory of Definite Integrals.—A course treating of the properties and methods of computing definite integrals, including a study of methods of approximation, improper definite integrals, Eulerian integrals, multiple integrals, with many problems and applications. Prerequisite: course 47. Mj. Summer, PROFESSOR SLAUGHT; Winter, PROFESSOR BLISS.

50. Fourier Series and Bessel Functions.— (*a*) A study of the properties of Bessel functions in connection with the solution of a variety of physical problems where they occur directly. (*b*) Trigonometric and Bessel series as solutions of partial differential equations. Byerly's "Fourier Series." Mj. Spring, ASSOCIATE PROFESSOR LUNN. [Not given in 1919.]

III. GRADUATE COURSES

NOTE.—Students should register for graduate courses only after consultation with instructors.

65A, B, C, D. Reading and Research in Pure Mathematics.—When in the judgment of the Department it is advisable that students undertake definite mathematical reading and research not closely connected with any current lecture course or seminar, this work will be directed by PROFESSOR MOORE, PROFESSOR DICKSON, PROFESSOR BLISS, OR PROFESSOR WILCZYNSKI. Mj. or DMj. each Quarter.

66A, B, C. Reading and Research in Applied Mathematics.—Advisable reading and research will be directed by PROFESSOR MOORE, PROFESSOR MYERS, OR ASSOCIATE PROFESSOR LUNN. Mj. or DMj. each Quarter.

71. Theory of Numbers.—Introductory course. Theory of congruences, the quadratic reciprocity theorem, and the theory of quadratic forms. Mj. Autumn, PROFESSOR DICKSON.

74. Theory of Algebraic Numbers.—Prerequisite: course 71. Mj. Winter, PROFESSOR DICKSON.

75. History of the Theory of Numbers.—Development from the historical standpoint of fundamental topics in the theory of numbers. The course is an introductory one, open to Senior college students after consultation with the instructor. Mj. Spring, 1921, PROFESSOR DICKSON.

81. Substitution Groups and Algebraic Equations.—An introduction to the theory of groups of substitutions and the Galois theory of algebraic equations, with applications to geometry. Text: Miller, Blichfeldt, and Dickson's *Theory and Applications of Finite Groups*. Mj. Winter, 1921, PROFESSOR DICKSON.

82. Finite Groups.—Selected topics on substitution groups, abstract groups, finite linear and collineation groups. Text as in course 81. Mj. Spring, 1920, PROFESSOR DICKSON.

84. Continuous Groups.—An illumination of the fundamental concepts and theorems of the Lie theory in connection with various classes of problems of geometry and differential equations. Mj. Summer, 1921, PROFESSOR BLISS.

91. Introduction to Higher Algebra.—Properties of matrices, invariant factors, and elementary divisors; algebraic theory of a single quadratic or bilinear form; theory of pairs of quadratic or bilinear forms. Geometrical applications. Based largely upon Bôcher's *Introduction to Higher Algebra*. Mj. Autumn, 1920, PROFESSOR DICKSON.

93. Theory of Algebraic Invariants.—An introduction to the non-symbolic theory of invariants of binary forms, with applications to geometry, followed by an explanation of the symbolic notation, with practice in its use. Based on Dickson's *Algebraic Invariants*. Mj. Summer, 1918; Winter, 1920, PROFESSOR DICKSON.

98. Linear Algebras.—An introduction to the theory of hypercomplex numbers, with attention to quaternions, the relations of the theory to matrices, bilinear forms, and groups. Text: Dickson's *Linear Algebras*, 1914, Cambridge Tracts on Mathematics and Mathematical Physics. Mj. Spring, PROFESSOR DICKSON.

101. Theory of Functions of a Real Variable.—A study of the existence theorems for implicit functions, ordinary and partial differential equations, and their applications in Analysis, especially to the Calculus of Variations. Mj. Autumn, 1919, PROFESSOR BLISS.

102. Ordinary Linear Differential Equations of the Second Order.—Existence theorems (real case), the analogy between linear algebraic and linear differential equations, theorems of comparison and oscillation, characteristic numbers and functions, expansion of arbitrary functions, Green's functions. Prerequisite: an elementary knowledge of the theory of functions of a real variable. Mj. [Not given in 1918–19.]

104. Calculus of Variations.—Examples illustrating the various types of problems. The differential equations of a curve which minimizes a definite integral in a space of two or more dimensions. Other properties of a minimizing curve as deduced by Legendre, Weierstrass, and Jacobi for the case of the plane. Conditions which insure the existence of a minimum. Isoperimetric problems and the more general problems of Lagrange and Mayer. An introduction to the theory of double integrals. Prerequisite: course 101. Mj. Summer, 1918; Winter, 1920, PROFESSOR BLISS.

105. Functions of Lines.—Special cases which occur in the calculus of variations and the theory of integral equations. The derivations of Volterra and the differentials of Fréchet, with applications to maxima and minima and implicit functions. The theory of composition of functions and the solution of general types of integral and integro-differential equations. Prerequisite: course 104. Mj. Spring, 1920, PROFESSOR BLISS.

106. Partial Differential Equations.—The geometrical theory of equations of the first order. Linear equations. Systems of equations of the first order. Introduction to equations of the second order. Applications to geometry and physics. Mj. Spring, PROFESSOR BLISS.

108. Differential Equations from the Standpoint of Lie.—The relations between continuous groups and differential equations. The Picard-Vessiot theory of linear differential equations. Mj. Winter, PROFESSOR BLISS.

111. Classes of Functions and Functional Operations in General Analysis.—Based on Moore's *Introduction to a Form of General Analysis*. The general analysis in question is the theory of systems of classes of functions, functional operations, etc., involving at least one general variable on a general range. A general variable is a variable entering the theory without direct characterization as to quality or range of variation. A real- and single-valued function ξ of a general variable p has as especially important particular instances: (I) a real

number ξ, the variable p having only one value; (II) an n-partite real number $\xi=(\xi_1, \ldots, \xi_n)$, or point ξ in real space of n dimensions, the variable p having the values $p=1, 2, \ldots, n$; (III) an infinite sequence $\xi=(\xi_1, \xi_2, \ldots, \xi_n, \ldots)$ of real numbers, the variable p having the values $p=1, 2, \ldots, n, \ldots$; (IV) a function ξ or $\xi(p)$ of the variable p on the linear interval $0\leqq p\leqq 1$ of the real number system. The first part of this introductory course considers certain fundamental closure and dominance properties of classes of functions of a general variable, properties possessed in particular by the class: (I) of all real numbers; (II) of all n-partite real numbers; (III_0) of all numerical sequences converging to zero; (III_1) of all absolutely convergent series of real numbers; (IV) of all continuous functions of p on the interval $0\leqq p\leqq 1$. The course presupposes a knowledge of the elements of the theory of functions of real variables. For second-year graduate students. Mj. Autumn, 1919, PROFESSOR MOORE.

112. Matrices in General Analysis.—Hermitian matrices of positive type and associated integration processes. A generalization of the work of Hilbert and Hellinger with reference to an arbitrary hermitian matrix of positive type. For second-year graduate students. Mj. Autumn, PROFESSOR MOORE.

113, 114. Theory of Functions of Infinitely Many Variables in General Analysis.—Prerequisite: course 112. Two consecutive majors. Winter, Spring, PROFESSOR MOORE.

115, 116. Integral Equations in General Analysis.—Application of the methods of course 111 to a study of the general Fredholm and Hilbert-Schmidt theories of integral equations. Two consecutive majors. Winter, Spring, 1920, PROFESSOR MOORE.

117. Differential Equations in General Analysis.—Determination and study of functions of a real valuable t and a general variable p, which satisfy a differential equation with respect to t. Mj. Summer, First Term, PROFESSOR MOORE.

121. Theory of Functions of the Complex Variable.—Introduction to the algebra and calculus of complex numbers and their geometric representation; conform representation. The theory of power series and the properties of analytic functions. Introduction to the theory of Riemann surfaces. Prerequisite: courses 47 and 49. Mj. Summer, PROFESSOR RICHARDSON; Spring, PROFESSOR BLISS.

122. Algebraic Functions.—The analytic character of an algebraic function and its geometrical representation by means of a Riemann surface. Abelian integrals on the Riemann surface, with especial attention to the hyperelliptic case. Abel's theorem. Introduction to the theory of the inversion of Abelian integrals. Prerequisite: course 121. Mj. Winter, 1921, PROFESSOR BLISS.

123. Elliptic Functions.—Elliptic integrals and the Weierstrassian theory of elliptic functions. Applications of elliptic functions. Mj. Spring, 1921, PROFESSOR BLISS.

130. Foundations of Geometry.—A critical study of geometry by the method of postulates based on the work of Hilbert and his successors. Mj. Spring, PROFESSOR MOORE. [Not given in 1919.]

141. Analytic Projective Geometry.—Analytic treatment of the projective properties of the straight line and of the conic sections. Prerequisite: familiarity with the fundamental concepts of projective geometry and a good knowledge of the calculus. Mj. [Not given in 1918–19.]

142. Higher Plane Curves.—General properties of algebraic curves. Special study of the curves of the third and fourth order. Mj. Summer, PROFESSOR BLISS.

144. Line Geometry.—The line co-ordinates of Plücker and Klein. Complexes, congruences, and ruled surfaces. Prerequisite: course 31. Mj. Spring, 1921, PROFESSOR WILCZYNSKI.

145. Higher Geometry.—A general survey of the principal methods and results of recent geometric research. The various systems of co-ordinates and

space elements, the rôle of the group concept, and the cultivation of space intuition by the use of models. Prerequisite: Differential Equations, Projective Geometry, and Solid Analytic Geometry. Mj. Spring, 1920, PROFESSOR WILCZYNSKI.

151, 152. Metric Differential Geometry.—The application of the Calculus to the metric theory of twisted curves and surfaces in space. Prerequisite: course 31. Two consecutive majors, Autumn, 1920, Winter, 1921, PROFESSOR WILCZYNSKI.

154, 155.—Projective Differential Geometry I, II.—This course gives a brief account of Lie's theory, with applications to the theory of invariants of systems of linear differential equations. The projective differential properties of plane and space curves, of surfaces and congruences, then present themselves as a result of interpreting this invariant theory geometrically. Text: Wilczynski's *Projective Differential Geometry of Curves and Ruled Surfaces.* (B. G. Teubner, Leipzig, 1906.) Prerequisite: an elementary knowledge of differential equations and projective geometry. Two consecutive majors, Autumn, Winter, PROFESSOR WILCZYNSKI.

156. Theory of Plane Curves.—Projective and metric differential and integral properties. Texts: Salmon's *Higher Plane Curves* and Wilczynski's *Projective Differential Geometry of Curves and Ruled Surfaces.* Prerequisite: an elementary knowledge of differential equations and projective geometry. Mj. PROFESSOR WILCZYNSKI. [Not given in 1918–19.]

157. Theory of Ruled Surfaces and Space Curves.—Primarily from the point of view of projective differential geometry. Text: Wilczynski's *Projective Differential Geometry of Curves and Ruled Surfaces.* Prerequisite: course 156. Mj. PROFESSOR WILCZYNSKI. [Not given in 1918–19.]

158. Theory of Surfaces and Congruences, with special emphasis upon the projective differential properties.—Prerequisite: Mathematics 157. Mj. PROFESSOR WILCZYNSKI. [Not given in 1918–19.]

160. Vector Analysis.—The elements of vector algebra, vector differentiation and integration, and the linear vector function; illustrated by typical applications to geometry, mechanics, and physics. Prerequisite: courses 31 and 49. Mj. Autumn, 1919, ASSOCIATE PROFESSOR LUNN.

162. Applications of Vector Analysis in the Theory of Electromagnetism.—Formulation of the Maxwell-Lorentz theory in terms of vector analysis. Hydrokinetic analogies and the geometry of scalar and vector fields. Fundamental problems in integration. Introductory study of vectors in four dimensions. Prerequisite: course 160. Mj. Winter, 1920, ASSOCIATE PROFESSOR LUNN.

163. Theory of Attraction and the Potential.—The potential function of gravitation and electrostatics; Laplace's equation, Green's functions, and harmonic analysis; extensions to cases of heterogeneous media, with sketch of the abstract theory as related to linear differential equations of the second order. Emphasis will be laid on the solutions of illustrative problems. Pierce's *Newtonian Potential Function.* Prerequisite: courses 49 and 160. Mj. Autumn, 1920, ASSOCIATE PROFESSOR LUNN.

164. Dynamics of Oscillatory Systems: Theory of Sound.—Mj. Winter, ASSOCIATE PROFESSOR LUNN.

166. Hydrodynamics.—Kinematics of continuous media and dynamical theory of typical forms of motion in perfect and viscous fluids, with special emphasis on analytic methods of general use in mathematical physics. Mj. Autumn, 1921, ASSOCIATE PROFESSOR LUNN.

167. Theory of Elasticity.—The geometry of strain in a continuous medium, dynamic relations of stress and strain; detailed study of selected problems in the equilibrium and motion of elastic solids. Prerequisite: Advanced Calculus and Analytic Mechanics. Mj. ASSOCIATE PROFESSOR LUNN, [Not given in 1918–19.]

170. Probability and Statistics.—The theory of average and probability for finite and infinite sets of elements; the statistical treatment of observations and the method of least squares; introduction to statistical mechanics, with examples from the theories of molecules and electrons. Prerequisite: Differential Equations. Mj. Associate Professor Lunn. [Not given in 1918–19.]

171. Statistical Mechanics.—This course deals with the mathematical methods used in the treatment of those physical theories where the magnitudes directly accessible to measurement are conceived as averages of multitudes of elements and physical laws are interpreted as examples of statistical regularity. A brief preparatory treatment of the notions of statistics and of the main features of the theory of probability, with some examples in geometry and kinematics, will lead to the main work of the course, in the kinetic theory of gases, the electron theory of metals, and some aspects of the theory of radiation. Prerequisite: thorough knowledge of the Calculus. Mj. Winter, Associate Professor Lunn. [Not given in 1919.]

172. Partial Differential Equations of Mathematical Physics; the Conduction of Heat.—A study of certain typical linear partial differential equations occurring in the analytic representation of physical theories and of the functional expansions of solutions satisfying given boundary conditions, with special reference to the concrete phenomena and physical analogies from which the abstract theory has been generalized. Prerequisite: courses 49 and 160. Mj. Winter, 1921, Associate Professor Lunn.

178. The Theory of Relativity.—After a brief historical introduction on the notion of relativity of time and space in its classic or Newtonian form, the course will be devoted to a study of the recent theory initiated by Einstein and Minkowski as a geometry of space and time adapted to the representation of physical laws. Special attention will be given to the discrimination between the logical elements of the theory and the special concrete interpretations that may be used in the formulation of experimental results. Mj. Summer, 1921, Associate Professor Lunn.

Attention is called to the following courses in the Department of Physics:

27. Units and Dimensions.—The theory of units and dimensions as applied to the measurement of concrete magnitudes and the mathematical transcription of physical experiments. Physical similitude and the interpretation of models. Numerical computations and the reduction of observations. Prerequisite: General Physics and some knowledge of Calculus. Mj. Summer, 7:10, Associate Professor Lunn.

64. Electromagnetic Theory.—(*a*) The main experimental facts of electromagnetism and their generalization so far as covered by the Maxwell theory in its abstract form; special problems concerning steady fields, induction, and electromagnetic waves. M. First Term. (*b*) The electronic interpretation and extension of the Maxwell theory; electromagnetic mass; theory of radiation and conduction; problems relating to moving bodies. M. Second Term, Summer, 8:10, Associate Professor Lunn.

For descriptions of the following courses see the announcement of the Department of Physics:

173. Physics 63. Geometric Optics.—Mj. Spring, Associate Professor Lunn.

174. Physics 11. Heat and Molecular Physics.—Mj. Autumn, Associate Professor Lunn.

175. Physics 51. Thermodynamics.—Mj. Winter, Associate Professor Lunn.

176. Physics 67. Radiation and Quantum Theory.—Mj. Spring, Associate Professor Lunn.

177. Electron Theory. Physics 52.—Mj. Autumn, Associate Professor Lunn.

CONSPECTUS OF COURSES OFFERED BY THE DEPARTMENT OF MATHEMATICS, 1918–19

Summer, 1918	Autumn, 1918	Winter, 1919	Spring, 1919
1. Plane Trigonometry (Roever)	00. Advanced Algebra (———)	01. Plane Geometry I (———)	02. Plane Geometry II (———)
2. College Algebra (First Term) (Moore)	1. Plane Trigonometry (*a*) (Slaught) (*b*) (Laves)	1. Plane Trigonometry (*a*) (Young) (*b*) (———)	1. Plane Trigonometry (*a*) (Slaught) (*b*) (———)
3. Analytic Geometry (Young)	2. College Algebra (Moore)	2. College Algebra (———)	2. College Algebra (Young)
18. Calculus I (Richardson)	3. Analytic Geometry (Dickson)	3. Analytic Geometry (Moore)	3. Analytic Geometry (Slaught)
19. Calculus II (Slaught)	7. Applied Mathematics I (Lunn)	8. Applied Mathematics II (Lunn)	9. Applied Mathematics III (Lunn)
23. Numerical Equations (First Term) (Dickson)	18. Calculus I (Wilczynski)	18. Calculus I (Young)	19. Calculus II (Young)
24. Determinants and Symmetric Functions (Second Term) (Dickson)	Analytic Mechanics I (Laves)	19. Calculus II (Wilczynski)	20. Calculus III (Wilczynski)
40. Topics in Geometry (Young)	47. Differential Equations (Slaught)	22. Theory of Equations (Dickson)	31. Solid Analytics (Dickson)
41. Descriptive Geometry (Roever)	71. Theory of Numbers (Dickson)	Analytic Mechanics II (Laves)	34. Limits and Series (Moore)
49. Definite Integrals (Slaught)	112. Matrices in General Analysis (Moore)	49. Definite Integrals (Bliss)	98. Linear Algebra (Dickson)
93. Algebraic Invariants (Dickson)	154. Projective Differential Geometry I (Wilczynski)	74. Algebraic Numbers (Dickson)	105. Functions of Lines (Bliss)
104. Calculus of Variations (Bliss)	174. Heat and Molecular Physics (Lunn)	108. Differential Equations (Lie Theory) (Bliss)	106. Partial Differential Equations (Bliss)
121. Functions Complex Variable (Richardson)	177. Electron Theory (Lunn)	113. Functions of Infinitely Many Variables I (Moore)	114. Functions of Infinitely Many Variables II (Moore)
117. Differential Equations in General Analysis (First Term) (Moore)		155. Projective Differential Geometry II (Wilczynski)	121. Functions Complex Variable (Bliss)
142. Higher Plane Curves (Bliss)		175. Thermodynamics (Lunn)	173. Geometric Optics (Lunn)
Physics 27. Units and Dimensions (Lunn)		Physics 68. Theory of Sound (Lunn)	176. Radiation and Quantum Theory (Lunn)
Physics 64. Electromagnetism (Lunn)			

THE DEPARTMENT OF ASTRONOMY AND ASTROPHYSICS

OFFICERS OF INSTRUCTION

Edwin Brant Frost, A.M., Sc.D., Professor of Astrophysics; Director of the Yerkes Observatory.

Sherburne Wesley Burnham, A.M., Sc.D., Emeritus Professor of Practical Astronomy at the Yerkes Observatory.

Edward Emerson Barnard, A.M., Sc.D., LL.D., Professor of Practical Astronomy at the Yerkes Observatory.

‡Forest Ray Moulton, Ph.D., Professor of Astronomy; Major, U.S.R., Ordnance Department.

Kurt Laves, Ph.D., Associate Professor of Astronomy.

John Adelbert Parkhurst, S.M., Assistant Professor of Practical Astronomy at the Yerkes Observatory.

Storrs Barrows Barrett, A.B., Assistant Professor of Astrophysics; Secretary and Librarian of the Yerkes Observatory.

William Duncan MacMillan, Ph.D., Assistant Professor of Astronomy.

Georges Van Biesbroeck, Dr.Eng., Assistant Professor of Practical Astronomy at the Yerkes Observatory.

Oliver Justin Lee, S.M., Ph.D., Instructor in Practical Astronomy at the Yerkes Observatory.

FELLOWS, 1917–18

Israel Albert Barnett, S.M. Hannah Bard Steele, A.M.

INTRODUCTORY

The work of the Department of Astronomy and Astrophysics is divided into two parts: (1) Work at the University, comprising: (*a*) elementary instruction in general Astronomy, both theoretical and practical; (*b*) preliminary training in the principles and methods of work underlying the science of Astrophysics (given in part in the Department of Physics); (*c*) graduate and research work in Celestial Mechanics. (2) Graduate and research work in Practical Astronomy and Astrophysics in the Yerkes Observatory at Williams Bay, Wisconsin. (1) At the University, in the work given by Professor Moulton, Associate Professor Laves, and Assistant Professor MacMillan, emphasis will be laid on the development of the mathematical principles and methods which form the basis of the physical sciences. In addition to the courses in Descriptive Astronomy, Introduction to Celestial Mechanics, and Analytic Mechanics, courses on Periodic Orbits and in the various other branches of Celestial Mechanics will be given within periods not exceeding three years. The most fundamental subjects will be arranged so as to recur at regular intervals, while other more special topics will vary from time to time. The general object of the instruction will be to give experience and preliminary training in the work of observation and reduction; to furnish the student an adequate mathematical basis for successful work in Celestial Mechanics, and to direct research work in Celestial Mechanics. The

‡ Absent on leave.

Departmental Club meets fortnightly for the review of memoirs and books and for the presentation of results of research. The club is conducted by the members of the Faculties of Mathematics and Mathematical Astronomy. Graduate students of Mathematical Astronomy are expected to attend regularly and, so far as possible, to participate actively in the meetings of the club. (2) At the Yerkes Observatory the advanced student is made familiar with modern methods of research in various branches of Practical Astronomy and Astrophysics. The rapid development of the latter science within the last two decades has been fully recognized in the equipment of the Observatory; the special laboratory facilities make some investigations possible which cannot be carried on where the equipment is less complete. In general, the work in progress during the year 1918–19 will include: researches in solar physics with the spectroscope, spectroheliograph, and photoheliograph; micrometric observations of double stars, planets, satellites, nebulae, and comets; studies of photographic stellar spectra and determinations of motions in the line of sight; photography of stars, comets, nebulae, etc.; photographic investigations of stellar parallax; research in visual and photographic photometry; special astrophysical researches. The opportunity of taking part in these investigations is deemed of more advantage to the qualified student than set courses of instruction; but regular programs of work, with courses of collateral reading, will be laid out as conditions require. During the Summer Quarter illustrated lectures particularly intended for graduate students are given on one evening of each week by members of the staff. The Astronomical Club also meets regularly—weekly during the Summer Quarter—for the discussion of assigned topics in Astronomy and Astrophysics.

FACILITIES

For instruction in Practical Astronomy a students' observatory is maintained. It is equipped with a modern Warner & Swasey equatorial telescope of 6½ inches aperture, which is provided with a filar micrometer, a 5-inch refractor, a 3-inch Bamberg transit instrument, a Bamberg universal instrument, a Riefler sidereal clock, a chronometer, and various smaller accessories. The laboratory courses offered by the Department of Physics afford excellent preliminary training for the work in Astrophysics.

For a description of the Yerkes Observatory see the *Annual Register* of the University of Chicago, Part V. An illustrated pamphlet of 24 pages, describing the observatory in detail, may be obtained on application.

DEGREES

The Master's degree.—Students working for a Master's degree in Astronomy are advised to choose three majors of graduate work in the Department of either Mathematics or Physics and six majors in the Department of Astronomy from courses numbered 5 to 10, 22, and 23. Those working for the Master's degree in Practical Astronomy or Astrophysics at the Yerkes Observatory are not required to spend part of their time at the University, although this is advised where possible.

The degree of Doctor of Philosophy.—The courses prescribed for the Master's degree together with three other graduate courses will meet the requirement for the Doctor's degree where Astronomy is the minor subject.

Candidates for the Doctor's degree, with Astronomy as major subject, are expected to take a number of courses in Mathematics and Physics. Students intending to specialize in Mathematical Astronomy will be required to take Advanced Integral Calculus, Differential Equations, and Theory of Functions of a Complex Variable; students intending to specialize in the lines of Astrophysics will be required to take the work in Theoretical Physics, Advanced Experimental Physics, Sound and Light, and Physical Manipulation. The courses in Astronomy which will be required depend on the phase of the subject which the candidate elects for his work. Students specializing in Mathematical Astronomy are expected to spend six months at the Yerkes Observatory, and those working in Practical Astronomy and Astrophysics are expected to spend at least two quarters at the University.

COURSES AVAILABLE FOR UNDERGRADUATES

SEQUENCES

3A and B, Descriptive Astronomy; 2, Spherical Trigonometry, with applications; 5, 6, Analytic Mechanics; 7A and B, Practical Astronomy; 10, Spectroscopy and Astrophysics; 22, 23, Celestial Mechanics; Mathematics 3, Analytic Geometry; 18, 19, Calculus; Physics 3, Mechanics, Molecular Physics, Heat; 4, Electricity, Sound, and Light.

The Department offers no nine-major sequences.

SECONDARY SEQUENCES

I. Astronomy

Courses 3A, 3B, 2, 7A, 7B, 10.

II. Astronomy and Mathematics

Courses 3, 18, 19 in Mathematics, 5, 6, 22 in Astronomy.

III. Astronomy and Physics

Courses 3A, 3B, Physics 3, 4, Astronomy 7, 10.

COURSES OF INSTRUCTION

A. JUNIOR COLLEGE COURSES

1. Descriptive Astronomy (shorter course).—An elementary course, dealing with fundamental facts, principles, and methods. Frequent access to the students' observatory. Mj. Summer, PROFESSOR MOULTON; Spring, PROFESSOR MOULTON AND ASSISTANT PROFESSOR MACMILLAN.

2. Spherical Trigonometry with Applications to Astronomy.—Prerequisite: Plane Trigonometry. Mj. Winter, ASSOCIATE PROFESSOR LAVES.

3A and 3B. Descriptive Astronomy (longer course; 1 not prerequisite).—A two-quarter course dealing with the fundamental facts and principles of Astronomy. Modern as well as classical methods and results are brought into full discussion. The observational side of the subject also is emphasized. Prerequisite: Plane Trigonometry. Mj. Winter and Spring, ASSISTANT PROFESSOR MACMILLAN.

4. Introduction to Surveying (Mathematics 1).—Mj. Spring, ASSOCIATE PROFESSOR LAVES.

B. SENIOR COLLEGE COURSES

5. Analytic Mechanics (Statics).—An introductory course. Prerequisite: Mathematics 18, 19. Mj. Autumn, ASSOCIATE PROFESSOR LAVES.

6. Analytic Mechanics (Dynamics).—Prerequisite: Mathematics 18, 19. Mj. Winter, ASSOCIATE PROFESSOR LAVES.

7. Spherical and Practical Astronomy.—Determination of time, latitude, and longitude. Prerequisite: Astronomy 1 and Mathematics 3. Mj. Spring, ASSOCIATE PROFESSOR LAVES; Summer, ASSISTANT PROFESSOR MACMILLAN.

8. Practical Astronomy I.—Observations of binary stars and determination of their orbits. Mj. Autumn, ASSOCIATE PROFESSOR LAVES. [Not given in 1918–19.]

9. Practical Astronomy II.—Observations of satellites and determination of orbits of satellites. Mj. Autumn, ASSOCIATE PROFESSOR LAVES.

10. Spectroscopy and Astrophysics (Physics 24).—A non-technical treatment of the growth of Spectroscopy, with applications to solar and stellar phenomena. Mj. Spring, PROFESSOR GALE.

C. GRADUATE COURSES

22. Introduction to Celestial Mechanics I.—Gravitational theory of sun's heat, central forces, potential and attraction of finite bodies, properties of conic section motion. Prerequisite: Mathematics 18, 19. Mj. Winter, ASSISTANT PROFESSOR MACMILLAN.

23. Introduction to Celestial Mechanics II.—Determination of orbits, special cases of the problems of three bodies: the Lunar Theory geometrically considered; variation of the elements and absolute perturbations. Mj. Spring and Summer, ASSISTANT PROFESSOR MACMILLAN.

31–36. Research Courses at the Yerkes Observatory.—The Yerkes Observatory is open only to graduate students who have completed the necessary preliminary studies and have had the requisite experience in practical laboratory and observatory work. Students wishing to work at the Observatory should first consult the Director of the Yerkes Observatory, Williams Bay, Wis., and obtain his approval. DMj. or 3Mjs. each Quarter, PROFESSORS AND INSTRUCTORS resident at Yerkes Observatory.

41. Theory of Planetary Motion.—Prerequisite: Astronomy 22 and 23. Mj. Autumn, PROFESSOR MOULTON. [Not given in 1918–19.]

42. The Lunar Theory.—Prerequisite: Astronomy 22 and 23, Mathematics 121. Mj. Winter, PROFESSOR MOULTON. [Not given in 1918–19.]

43. Application of the Methods of Periodic Orbits to the Lunar Theory.—Prerequisite: Astronomy 42. Mj. Spring, PROFESSOR MOULTON. [Not given in 1918–19.]

51, 52. Modern Theories of Analytic Differential Equations with Applications to Celestial Mechanics and Periodic Orbits I, II.—Properties of the solution of a general system of differential equations of the nth order as functions of the independent variable, of the parameters, of the initial values of the dependent variables. Solutions developed as power series in the independent variable, in the parameters, in the initial values of the dependent variables, by the Cauchy-Lipschitz process, by the Picard approximation process, by continued variation of parameters. Applications to elliptic and hyperelliptic functions and to periodic solutions of the problem of three bodies. Linear equations with applications to hypergeometric functions. Linear equations with periodic coefficients. Mj. Autumn and Winter, PROFESSOR MOULTON. [Not given in 1918–19.]

60. Periodic Solutions of the Problem of Three Bodies.—Mj. PROFESSOR MOULTON. [Not given in 1918–19.]

70. Theory of Figures of Equilibrium of Rotating Fluid Bodies.—This is an advanced course, including Poincaré's and Darwin's researches. Mj. PROFESSOR MOULTON. [Not given in 1918–19.]

80. The Problem of Three Bodies.—Mj. PROFESSOR MOULTON. [Not given in 1918–19.]

THE DEPARTMENT OF PHYSICS

OFFICERS OF INSTRUCTION

ALBERT ABRAHAM MICHELSON, PH.D., SC.D., LL.D., F.R.S., Professor and Head of the Department of Physics.

‡ROBERT ANDREWS MILLIKAN, PH.D., SC.D., Professor of Physics; Lieutenant Colonel, United States Reserves, National Reserve Council.

‡HENRY GORDON GALE, PH.D., Professor of Physics; Major, United States Reserves, Signal Corps.

‡CARL KINSLEY, A.M., M.E., Associate Professor of Physics; Captain, United States Reserves, Signal Corps.

HARVEY BRACE LEMON, PH.D., Assistant Professor of Physics.

‡ARTHUR JEFFERY DEMPSTER, PH.D., Instructor in Physics; Master Electrician, United States Navy.

FABIAN MILLER KANNENSTINE, S.B., Instructor in Physics.

CHARLES FREDERICK HAGENOW, A.M., Assistant in Physics.

OTTO KOPPIUS, S.B., Assistant in Physics.

YOSHIO ISHIDA, PH.D., Assistant in Physics.

RALPH ALANSON SAWYER, A.B., Assistant in Physics.

FELLOWS, 1917–18

EDWARD STOWE AKELEY, A.B.

MYRON EARLE GRABER, A.M.

INSTRUCTIONAL WORK

The instructional work in Physics is directed toward the following ends: (1) The training of original investigators in physics; (2) the training of men competent to fill college and university positions as teachers of physics; (3) the training of teachers of physics for secondary schools; (4) the training of pre-engineering and pre-medical students for later professional work; (5) the training of the general student in scientific methods of work and in the understanding of the place of physical science in the modern world. From the most elementary to the most advanced courses the laboratory and the problem method of instruction are emphasized.

FACILITIES

The Ryerson Physical Laboratory has been enlarged and remodeled with especial reference to offering the best facilities for research work. The entire lower floor and basement are given up to private research-rooms. A well-equipped shop, with skilled instrument-makers, furnishes opportunity for the construction of special pieces of research apparatus. The equipment has been selected with reference to the needs of research, and includes spectroscopic instruments of highest power, electrical apparatus for work in alternating and direct currents through all ranges of potential, and appliance for high and for low temperature work, including a liquid-air plant. The library of the Department is well equipped for research purposes. A Physics Club is conducted by the members of the Department, and meets regularly for the discussion of the results of research work done in the Ryerson Laboratory and elsewhere.

‡ Absent on leave.

COURSES AVAILABLE FOR UNDERGRADUATES

SEQUENCES

3, Mechanics; 4, Electricity; 5, Heat, Sound, and Light; 3S, Mechanics, Molecular Physics, and Heat; 4S, Electricity, Sound, and Light; 7, Lecture Demonstrations in Physics; 9, Elementary Wireless Telegraphy; Mathematics 7, 8, 9, Applied Mathematics (see under Mathematics Department); 11, Heat and Molecular Physics; 12, Light; 13, Electricity and Magnetism; 14, Pegadogy of Physics; 15, Mechanics and Wave-Motion; 16, 17, 18, 19, Experimental Physics; 20, Physical Manipulation; 21, Analytic Mechanics (Astronomy 5, 6); Educacation 62, Educational Psychology; 1, Principles of Education; Astronomy 3, Descriptive Astronomy (two majors); Mathematics 18, 19, Calculus.

Graduate courses in the Department may be substituted for courses 10 to 19 by students who have the prerequisites.

PRINCIPAL SEQUENCES

a) Courses 3, 4, 5, or 3S, 4S, 7, and any six majors chosen from courses 10 to 13; 15 to 19.

Physics and Mathematics

b) Courses 3, 4, 5, or 3S, 4S, 7, and any six majors from the following: Mathematics 18, 19; Astronomy 5, 6, and Physics 10 to 13; 15 to 18.

Teacher's Sequences

c) Courses 3, 4, 5, 7, or 3S, 4S, 7; 11, 14, 20; Education 62 and Philosophy 7.

Physics and Astronomy

d) Courses Physics 3, 4, 5, or 3S, 4S, 7; Astronomy 3 (two majors), with four majors selected from Physics 11–18, and Mathematics 18, 19.

Physics and Chemistry

e) Courses Physics 3, 4, 5, or 3S, 4S, 7; Chemistry 2S, 3S, and four majors selected from Physics 11–18, 18, and Mathematics 18, 19.

In any of the foregoing sequences graduate courses numbered 31 to 69 may be substituted for courses 10 to 18 by students who have the required prerequisites.

SECONDARY SEQUENCES

a) Courses 3, 4, 5, or 3S, 4S, 7, and three advanced majors in Physics.

b) Courses 3, 4, 5, or 3S, 4S, 7, and three majors from the following: 10 to 69, Astronomy 3 (two majors), Chemistry 2S, 3S; Mathematics 18, 19.

DEGREES

All candidates for the S.B. degree who elect their major work in Physics are required to take courses 3, 4, and 5, and either six majors selected from courses 10, 11, 12, 13, 15, 16, 17, 18, 19, 24, and 28, or three of these and three Senior College courses in one of the following departments: Mathematics, Astronomy, Chemistry, Geology, or Geography.

The Master's degree.—Candidates for the Master's degree in Physics are required to take eight majors in Physics and related subjects, and to present in addition a dissertation embodying the results of a laboratory problem. All courses in the Department numbered 10 or above, except course 20, will be counted in satisfaction of this requirement, but at least three majors selected from courses 10, 11, 12, 13, and 15 must be included.

The degree of Doctor of Philosophy.—Candidates for the Doctor's degree with Physics as a minor subject must take six of the following courses: 10, 11, 12, 13, 15, 16, 17, 18, 19, 24, 28, and three additional majors of graduate work. When Physics is one of two minor subjects, the courses must be arranged by consultation with the Department.

All candidates for the Doctor's degree with Physics as the major subject must take the following courses: 10, 11, 12, 13, 15, and 28, or their equivalent; three majors selected from courses 16, 17, 18, 19, 37, 38; courses 31–36, and three additional graduate courses selected by the student. Each candidate must also present a dissertation embodying the results of original research in some subject approved by the Department. The time required for the dissertation work generally varies from three to six quarters.

PREPARATION FOR TEACHING

Students preparing to teach Physics in secondary schools are expected to have completed courses 3, 4, 5, 14, 28, and not less than four of courses 10, 11, 12, 13, 15, 16, 17, 18, 19, and 24. See also courses in Physics in the School of Education.

LABORATORY FEE

There is a laboratory fee of $5.00 for all major courses involving laboratory work in the Department of Physics.

COURSES OF INSTRUCTION

I. JUNIOR COLLEGE COURSES

1. Elementary Physics.[1]—A first course in the elements of Physics designed primarily for students who do not present entrance Physics. Prerequisite: Algebra and Plane Geometry, one unit each. DM. Summer, First Term, Dr. Harrington; Mj. Autumn, Mr. Hagenow.

2. Elementary Physics.[1]—A continuation of the preceding course, covering the subjects of electricity, sound, and light. Prerequisite: course 1. DM. Summer, Second Term, Dr. Harrington; Mj. Winter, Mr. Hagenow.

3. Mechanics.—A general college course in mechanics presented mainly from the experimental point of view, but including one demonstration lecture each week. Prerequisite: entrance Physics or course 2. Mj. Autumn, 4 sections, Assistant Professor Lemon, Mr. Koppius, and Mr. Sawyer.

4. Electricity.—A general college course in electricity, presented mainly from the experimental point of view, but including one demonstration lecture each week. Prerequisite: course 3. Mj. Winter, 4 sections, Assistant Professor Lemon, Mr. Koppius, and Mr. Sawyer.

5. Heat, Sound, and Light.—A general college course in heat, sound, and light, presented mainly from the experimental point of view, but including one demonstration lecture each week. Prerequisite: course 4. Mj. Spring, 4 sections, Assistant Professor Lemon, Mr. Koppius, and Mr. Sawyer.

3S. Mechanics, Molecular Physics, and Heat.—A general college course in mechanics, molecular physics, and heat presented from the experimental point of view, not containing demonstration lectures. Prerequisite: entrance Physics or course 2 and Trigonometry. Mj. Summer, 2 sections; Winter, 2 sections, Mr. Koppius and Mr. Sawyer.

[1] Limited-credit course: After a student has credit for 18 majors but less than 27, these courses will be credited at one-half major each; after he has credit for 27 majors they will not be credited at all.

4S. Electricity, Sound, and Light.—A general college course in electricity, sound, and light presented from the experimental point of view, not containing demonstration lectures. Prerequisite: course 3S or courses 3 and 4. Mj. Summer, 2 sections; Spring, 2 sections, Mr. Koppius and Mr. Sawyer.

7. Lecture Demonstration Course.—A course of demonstration lectures covering the entire field of Physics designed to supplement courses 3S and 4S. Especial attention is given to modern points of view; the kinetic theory of heat, the atomic theory of electricity, and the electrical theory of matter receiving especial attention. The attempt is made to repeat a majority of the classical demonstrations of Kelvin, Faraday, Thomson, and others. This course includes the demonstration lectures of courses 3, 4, and 5. Prerequisite: courses 3S and 4S or their equivalent. Mj. Summer, Assistant Professor Lemon and Mr. Koppius.

9. Elementary Wireless Telegraphy.—A course of lectures and laboratory work consisting of elementary consideration of the fundamental laws and their applications to the circuits of modern wireless telegraph systems. Experimental adjusting of wireless telegraph circuits and practice in receiving the Continental code. Prerequisite: courses 3 and 4. Mj. Summer and Spring, Mr. Kannenstine.

Applied Mathematics I, II, III.—An intensive training course in mathematical methods for students who expect to undertake scientific work; in close connection with corresponding courses offered by the Departments of Physics and Chemistry. Students desiring to begin intensive training in Physics for future scientific service should register for these three courses which are designed to prepare them for Senior College work in Physics (see Mathematics 7, 8, 9 for more detailed announcement). Three consecutive majors.

II. SENIOR COLLEGE COURSES

10. Elementary Mathematical Physics.—A lecture course on the application of Elementary Calculus to Physics and Chemistry, and practice in the solution of problems. Prerequisite: Physics 4S or 5 and not less than one major of Calculus. Mj. Autumn, Professor Gale. [Not given in 1918–19.]

11. Heat and Molecular Physics.—A lecture course for advanced and graduate students, covering the Kinetic Theory, Capillarity, Elementary Thermodynamics, Solution, and Electrolysis. Prerequisite: Physics 4S or 5 and Calculus. Mj. Autumn, Associate Professor Lunn.

12. Light.—A lecture course for advanced students covering the more important sections of geometrical and physical optics. Prerequisite: Physics 4S or 5 and Calculus. Mj. Summer and Winter, Professor Gale. [Not given in 1918–19.]

13. Electricity and Magnetism.—A course of advanced work in Theoretical Electricity and Magnetism, with many applications to electrical and magnetic apparatus and measurements. Prerequisite: Physics 4S or 5 and Calculus. Mj. Winter, Mr. Kannenstine.

14. The Pedagogy of High-School Physics.—This course includes the following topics: the present high-school course in Physics, its development, requirements, and methods of presentation; the principles involved in the lecture demonstration, in the recitation and quiz, and in the laboratory experiments and notebook. The course is illustrated by a series of lecture demonstrations. It provides a survey of the whole field of Physics, with a special reference to the choice of subject-matter and effective methods of presentation in high-school classes. Prerequisite: a thorough knowledge of the first principles of Physics. Lecture, 9:00; Laboratory, 7:00. DMj. Summer. [Not given in 1918.]

15. Mechanics and Wave-Motion.—A lecture course on the physical meaning and the mathematical derivation of the fundamental equations of Mechanics and Wave-Motion. Prerequisite: Physics 4S or 5 and Calculus. Mj. Spring, Professor Gale. [Not given in 1918–19.]

16. Experimental Physics (Advanced): Molecular Physics and Heat.—A course of advanced laboratory work involving the determination of vapor pressures and densities, coefficients of friction of gases and liquids, molecular electrical conductivities, freezing- and boiling-points, latent and specific heats, high and low temperatures, radioactive constants, etc. Prerequisite: course 4S or 5. Mj. Spring. [Not given in 1918–19.]

17. Experimental Physics (Advanced): Light.—A course of advanced laboratory work in Light, consisting of accurate measurements in diffraction, dispersion, interference, and polarization. Prerequisite: course 4S or 5. Mj. Summer and Autumn, Assistant Professor Lemon and Mr. Hagenow.

18. Experimental Physics (Advanced): Electricity and Magnetism I.—Laboratory work of the same grade as courses 16 and 17, but consisting of measurements in Electricity and Magnetism. Prerequisite: Physics 4S or 5. Mj. Summer and Winter, Mr. Kannenstine.

19. Experimental Physics (Advanced): Electricity and Magnetism II.—Laboratory work accompanied by lectures consisting of the theory and operation of dynamos, motors, transformers, wireless-telegraph apparatus. Prerequisite: Physics 4S or 5. Mj. Spring, Mr. Kannenstine.

20. Physical Manipulation.—A series of exercises not provided in the regular courses of Experimental Physics, but important to the teacher or advanced student. It consists of the following groups:

Group A. *Shop Work* includes the cutting, filing, drilling, tapping, soldering, and polishing of metal, screw-cutting, and elementary lathework.

Group B. *Glass Work* includes the cutting, grinding, drilling, polishing, and testing of glass.

Group C. *Glass Blowing* includes the simpler processes in glass blowing, such as cutting, bending, and joining of tubes, blowing bulbs, sealing in electrodes, etc.

Group D. *Chemical Processes and Physical Preparations* include the silvering of glass, cleaning and distillation of mercury, preparation of fibers for suspension, and materials useful in experimental work. Group C only M. First Term. Repeated Second Term, Summer, Dr. Ishida.

24. Spectroscopy and Astrophysics.—A non-technical treatment of the growth of Spectroscopy, with applications to solar and stellar phenomena. Prerequisite: 15 majors. Mj. Spring, Professor Gale.

27. Units and Dimensions.—The theory of units and dimensions as applied to the measurement of concrete magnitudes and the mathematical transcription of physical experiments. Physical similitude and the interpretation of models. Numerical computations and the reduction of observations. Prerequisite: General Physics and some knowledge of Calculus. Mj. Summer, 7:10, Associate Professor Lunn.

28. Photographic Processes.—Lectures and laboratory work on the laws of photographic action. Effects of exposure and development on opacity and density; orthochromatism, plate grain, speed, intensification, reduction, and the applications of these to the photography of exceptional subjects. Prerequisite: Calculus. Mj. Autumn, Assistant Professor Lemon.

III. GRADUATE COURSES

31, 32, 33. Theoretical Physics.—A series of lectures chiefly in Theoretical Physics, Hydrodynamics, Elasticity, Capillarity, Molecular Physics, Thermodynamics, Wave-Motion, Sound, Optical Theories, Electricity, and Magnetism. 4 hours a week. Prerequisite: Physics 10, 11, and 13 and Calculus. Mj. Autumn, Winter, and Spring, Professor Michelson.

34, 35, 36. Theoretical Physics.—A series of lecture courses. Alternating with 31, 32, and 33. Prerequisite: same as for course 31. 3Mjs. Autumn, Winter, and Spring, Professor Michelson.

37, 38, 39. Experimental Physics.—A course of laboratory work, chiefly devoted to the repetition of classical experiments, such as Determination of the Mechanical Equivalent of Heat; Maxwell's "V"; Hertzian Oscillations; Relative and Absolute Wave-Lengths, etc. 10 hours a week. Prerequisite: Physics 16, 17, and 18. 3Mjs. Autumn, Winter, and Spring, Professors Michelson and Millikan and Assistant Professor Lemon.

40, 41, 42, 43. Research Course.—This course is intended for graduate students who are prepared to undertake special research. Except in the case of a purely mathematical problem, the entire time is to be devoted to work in the laboratory. DMj. Autumn, Winter, and Spring, Professors Michelson and Millikan and Assistant Professor Lemon.

***45. Aëronautics 1.**—A course of lectures accompanied by a few demonstration experiments on the mechanical principles of flight. Dynamic similitude, elementary aërodynamics of fluid resistance, and the classical theory of Rayleigh form the principal theoretical topics. Much time is given to the discussion of the experimental work of Eiffel and the National Physical Laboratory on flat and cambered aërofoils, lift and drift coefficients. The Phugoid theory of Lanchester, longitudinal lateral and directional stability are taken up, as well as the modern gyroscopic devices of control. Prerequisite: Calculus and Elementary Mechanics, or consent of instructor. Mj. Winter, Assistant Professor Lemon.

48. Spectrometry I.—Laboratory work in photographing and measuring the spectra of various elements. Use of the concave grating, echelon, and interferometer. Prerequisite: consent of the instructor. Mj. Spring, Assistant Professor Lemon.

51. Thermodynamics.—Lectures upon the fundamental principles underlying the mechanical theory of heat and the application of these principles to physical and thermochemical problems. Prerequisite: two years of college Physics and Calculus. 5 hours a week. Mj. Winter, Associate Professor Lunn.

52. Electron Theory I.—A course of graduate lectures covering the work of the last ten years on the electrical properties of gases, the electron theory, and radioactivity. Prerequisite: same as for course 51. 5 hours a week. Mj. Autumn, Associate Professor Lunn.

53. Electron Theory II.—A continuation of 52, dealing with the application of the electron theory to metallic conduction, to the Seebeck, Peltier, Thomson, and Hall effects, to optical phenomena in magnetic fields, to the subject of electromagnetic mass, etc. 5 hours a week. Mj. Professor Millikan. [Not given in 1918–19.]

55. Atomic Theories of Radiation and Their Experimental Basis.—A course of graduate lectures on recent theories of radiation, with especial reference to their relations to the laws of thermodynamics. Prerequisite: Elementary Thermodynamics. Mj. Spring, Associate Professor Lunn.

56. X-Rays and Theories of Atomic Structure.—A course of graduate lectures dealing with X-rays and the related phenomena, the study of which has thrown new light upon the structure of the atom and the relations of the atom and the molecule. Prerequisite: College Physics and Calculus. Mj. 8:00, Professor Millikan. [Not given in 1918–19.]

57. The Theory of Alternating Currents.—A discussion of transformers, transmission circuits, and the various types of dynamos and motors. Prerequisite: course 18 or 19 and Calculus. Mj. Mr. Kannenstine.

58. Transient Electrical Phenomena.—Theory and demonstration of current flow before the steady state is reached. Oscillations in power circuits and wireless-telephone and -telegraph transmission are discussed. Prerequisite: course 18 or 19 and Calculus. Mj. Spring and Summer, Mr. Kannenstine.

59. Modern Spectroscopy.—A lecture course on the theory and use of spectroscopic apparatus and a discussion of spectroscopic and astrophysical phenomena. Prerequisite: same as course 51. Mj. PROFESSOR GALE. [Not given in 1918–19.]

60. Light Waves and Their Uses.—A course of graduate lectures on recent developments in physical optics. Prerequisite: same as for course 51. Mj. PROFESSOR MICHELSON. [Not given in 1918–19.]

61. Physical Optics.—Lectures on the fundamental equations of Theoretical Optics and on recent experimental results. Prerequisite: same as for course 51. Mj. Summer, PROFESSOR GALE. [Not given in 1918–19.]

62. The Theory of Relativity.—After a brief historical introduction on the notion of relativity of time and space in its classic or Newtonian form, the course will be devoted to a study of the recent theory initiated by Einstein and Minkowski as a geometry of space and time adapted to the representation of physical laws. Special attention will be given to the discrimination between the logical elements of the theory and the special concrete interpretations that may be used in the formulation of experimental results. Mj. Summer, ASSOCIATE PROFESSOR LUNN. [Not given in 1918–19.]

63. Geometrical Optics.—The methods and principles of Geometrical Optics as applied to the designing of optical instruments and the interpretation of their performance. Theory of the ideal instrument and its approximate realization; aberrations; illumination and diffraction; special properties of particular instruments; characteristics of various types of optical glass. Mj. Spring, ASSOCIATE PROFESSOR LUNN.

64. Electromagnetic Theory.—(*a*) The main experimental facts of electromagnetism and their generalization so far as covered by the Maxwell theory in its abstract form; special problems concerning steady fields, induction, and electromagnetic waves. M. First Term, Summer; (*b*) The electronic interpretation and extension of the Maxwell theory; electromagnetic mass; theory of radiation and conduction; problems relating to moving bodies. Mj. Summer, ASSOCIATE PROFESSOR LUNN.

65. Theory of Wireless Telegraphy.—The fundamental laws and their application to the wireless telegraph circuits of the various operating systems. Prerequisite: Physics 13, 18, or 19 and Calculus. ½Mj. Winter, MR. KANNENSTINE.

66. Electrical Measurements in Wireless Telegraphy.—Experimental verification of wireless telegraph theories and the measurement of constants at high frequencies. Prerequisite: registration in 65. ½Mj. Winter, MR. KANNENSTINE.

67. Radiation and Quantum Theory.—This course will cover the theoretical and experimental development of the radiation laws out of which grew the first suggestion of an atomic theory of radiant energy. It will give a critical survey of the attempts to interpret the newer discoveries in the domain of specific heats in terms of the Quantum theory and will deal also with the photo-electric X-ray and optical phenomena which lend support to such a theory. Mj. Spring, ASSOCIATE PROFESSOR LUNN.

68. Theory of Sound.—Dynamical theory of production; transmission and reception of sound. Analysis and systems of vibrations. Illustrations by acoustic apparatus and musical instruments. Analogies in electromagnetic oscillations. Mj. Winter, ASSOCIATE PROFESSOR LUNN.

69. Physical Optics.—A theoretical treatment of optical phenomena in the realm of interference and diffraction. M. First Term, Summer, PROFESSOR MICHELSON.

70. Physics Club.—This organization, consisting of all instructors and graduate and advanced students in the Department, meets on Thursday of each week from 4:30 to 6:00 for the discussion of recent research.

THE DEPARTMENT OF CHEMISTRY

OFFICERS OF INSTRUCTION

JULIUS STIEGLITZ, PH.D., SC.D., CHEM. D., Professor and Chairman of the Department of Chemistry.

WILLIAM DRAPER HARKINS, PH.D., Professor of Chemistry.

HERMANN IRVING SCHLESINGER, PH.D., Associate Professor of Chemistry.

JEAN FELIX PICCARD, SC.NAT.D., Associate Professor of Organic Chemistry.

ETHEL MARY TERRY, PH.D., Assistant Professor of Chemistry.

JOHN WILLIAM EDWARD GLATTFELD, PH.D., Assistant Professor of Chemistry.

GERALD LOUIS WENDT, PH.D., Assistant Professor of Chemistry and Acting Curator.

‡LEO FINKELSTEIN, S.B., Instructor in General Chemistry. Chemical Service Unit, N.A., France.

‡WILLIS EUGENE GOUWENS, Curator. Public Health Service, Washington, D.C.

*SIDNEY MAURICE WEISMAN, S.B., Curator.

RAYMOND DAVID MULLINIX, S.B., Associate in Chemistry.

CLARENCE ADELBERT NASH, S.B., A.M., Associate in General Chemistry.

MARY WETTON, S.B., Associate in General Chemistry.

‡FREDERICK F. BLICKE, S.B., S.M., Research Associate. Trench Warfare Section, Engineering Department, Washington, D.C.

EDWARD N. ROBERTS, S.B., Assistant in Chemistry.

HOMER HENRY HELMICK, S.B., Assistant in Physical Chemistry.

JOHN EDWARD SCHOTT, S.B., Assistant in Organic Chemistry.

‡GEORGE L. CLARK, S.B., S.M., Assistant in Chemistry. Trench Warfare Section, Engineering Department, Washington, D.C.

‡LATHROP EMERSON ROBERTS, S.B., Assistant in General Chemistry. Chemical Service Unit, N.A., France.

ELMER N. BUNTING, Assistant in Quantitative Analysis.

LOUIS M. LARSEN, S.B., S.M., Assistant in Chemistry.

‡ANDREW T. MCPHERSON, S.B., Assistant in Chemistry. Bureau of Standards, Washington, D.C.

MARY MEDA RISING, S.B., Assistant in Organic Chemistry.

RAY QUINCY BREWSTER, S.B., A.M., Assistant in Organic Chemistry.

‡LESTER HELLERMAN, S.B., Assistant in Chemistry. Trench Warfare Section, Engineering Department, Washington, D.C.

HENRY MAY MCLAUGHLIN, B.S., A.M., Assistant in Chemistry.

GLADYS LEAVELL, S.B., Assistant in Chemistry.

MORRIS KHARASCH, S.B., Lecture Assistant.

MARION G. FRANK, Lecture Assistant.

‡ Absent on leave.

* Resigned.

FELLOWS, 1917–18

Ray Quincy Brewster, S.B., A.M.
R. S. Dean, S.B., S.M.
E. H. Grafton, S.B., S.M.
Herbert Hiram King, A.B., A.M., Swift Fellow.
David McLaren, A.M.
Charles H. Milligan, S.B., S.M. Ambulance Co., N.A., Camp Upton, Long Island.
Stephen Popoff, Loewenthal Fellow.
Mary Meda Rising, S.B., Edith Barnard Fellow.
Herman Vance Tartar, S.B., Swift Fellow.

INSTRUCTIONAL WORK

The Department aims to prepare students (1) for government and war service, (2) to teach in colleges or universities, (3) to teach in secondary schools, (4) to fill positions as technical experts or assistants in chemical industries, (5) to become analysts in commercial and sanitary laboratories. The elementary courses may be taken with advantage by students having none of these ends in view.

Special stress will be placed on thoroughness of preparation and the symmetrical development of the student's knowledge. The object of the courses will be not so much to train specialists as to prepare the student to undertake intelligently all kinds of work of a chemical nature. Those intending to become practical chemists will find a thorough course of purely scientific chemistry the best basis for future specialization in any branch of the subject. Those who incline toward inorganic chemistry will be required to do much physical and a considerable amount of organic work; those proposing to become organic chemists will be required to do work in inorganic chemistry of a more advanced nature than that given in the elementary and analytical courses, and some physical chemistry, etc. The test of time and the experiences of the graduates of the Department have fully justified this form of training.

RESEARCH

Students are encouraged to begin research work as soon as their preparation justifies it. Facilities for research in all lines, whether of inorganic, organic, radioactive, or physical chemistry, are provided. Special opportunities to pursue entirely independent research work, as guests of the University (see p. 7), will be given to maturer students who have already obtained the Doctor's degree. Besides a number of general University Fellowships which are usually allowed to the Department for candidates for the Ph.D. degree, there are three specially endowed Fellowships in Chemistry: the Loewenthal Fellowship, a memorial to Joseph B. Loewenthal, the Swift Fellowship, endowed by Mrs. Gustavus F. Swift, and the Edith Barnard Fellowship, a memorial to Edith Ethel Barnard, a former instructor, donated by her friends and family.

ARRANGEMENT OF COURSES

2, 3, 2S, 3S, General Chemistry, Inorganic; 4, Elementary Organic; 6, 7, 10, Qualitative Analysis; 8, 9, 11–19, Quantitative Analysis; 20–22, Elementary

Physical Chemistry; 25, Toxicology; 26, Detection of Poisons; 30–49, Organic Chemistry; 50–59, Advanced Inorganic Chemistry; 60–74, Advanced Physical Chemistry; 75–79, Radio-Chemistry; 83, Teaching of Chemistry; 90–101, Research.

REQUIREMENTS FOR DEGREES

THE DEGREE OF DOCTOR OF PHILOSOPHY

I. *Chemistry the primary subject.*—When the degree of Doctor of Philosophy in Chemistry is desired, the branch of chemistry touched by the dissertation is offered as a *major subject* and some other branch of chemistry as the *first minor* subject. Besides this, a sufficient knowledge of other fundamental phases of the science is required as well as sufficient work in a *second minor* subject in some other department. These conditions are complied with when the following specific requirements are fulfilled:

1. The presentation of a dissertation embodying the result of original research in General, Inorganic, Organic, Physico-organic, or Physical Chemistry, or Radioactivity. This must constitute a real contribution to knowledge, and the work is usually done under the direction of an officer of the Department.

2. The general requirements for all candidates, in advance of General Chemistry: courses 4,[1] 6–9, 20, and two majors selected from courses 10, 11, 13–19, 21–22, 30–32.

3. In addition to the above, one of the following specific sets of requirements, arranged according to the dissertation subject:

General Chemistry and Inorganic Chemistry: courses 21, 22, 63, 35 (or 30 and 31), and 50–52, and one major taken from courses 13–19, 30–37, 64; *Organic Chemistry:* courses 30–32, 35[2]–37, 50, and one major from 10, 13–19, 51, 52, 31, 21, 22, 54; *Physico-organic Chemistry:* courses 30–32, 35[2], 36, 50, 21, and 22, and one major taken from courses 10, 13–19, 51, 52, 63, and 64. *Physical Chemistry*: courses 21, 22, 35 (or 30 and 31), 50, 51, 63, 64, and one major taken from courses 10, 13–19, 30–32, 35–37, 52. *Radioactivity:* courses 21, 50, 63, 64, 75, 76, and Physics 52 (Electron Theory), and one major taken from courses 10, 13–19, 22, 30–32, 35–37, and 52. In addition to one set of these specific requirements at least six half-majors will be chosen from the special lecture course 41–46, 54–59, 65–79, 83. The research work will require from four to six quarters.

4. Sufficient work of an advanced character in another department to make a *second minor* of *three majors*. In addition to the regular minor subject, candidates are advised to take Mineralogy and Crystallography. The following are the requirements for such a minor in various departments: (*a*) In *Physics:* three of the courses 11, 12, 13, 16, 17, 18, 19, 48, 49, 51, 52, 53, 55 or 56; courses 3, 4, 5 are prerequisite to these. (*b*) In *Physiological Chemistry:* three majors selected from 24, 25, 26, 37, 38, 39, or 42. (*c*) In *Geology:* courses 15, 16, and 52 or their equivalent. Courses 7 or 8, and 11, 12, 14 would be prerequisite to these courses. (*d*) In *Geography:* courses 17, 18, 21, and their prerequisite courses. (*e*) In *Hygiene and Bacteriology:* course 12 and two and one-half majors in course 15; courses 2 and 3 are prerequisite to these. With permission, course 10 or 11 may be substituted for course 12.

[1] Course 4 may be omitted when advanced work in Organic Chemistry is taken.

[2] Course 35 will be omitted when courses 30–31 have included laboratory work.

II. *Chemistry the secondary subject.*—When Chemistry is a secondary subject, the requirement is determined after conference with the Head of the Department in which the major work is done. Courses 6, 7, and 8, and six other majors in advance of 8, will be required when Chemistry is the only secondary subject; courses 6, 7, and 8, and three other majors, when Chemistry is one of two secondary subjects. Elementary Physical Chemistry or Organic Chemistry, according as the major subject belongs to the Physical or the Biological Group, is recommended.

THE MASTER'S DEGREE

For the Master's degree in Chemistry a dissertation and eight majors of graduate work in Chemistry are required if all the work is in Chemistry. These majors must be selected from courses in advance of 9, with the approval of the Chairman of the Department. Courses prerequisite to these must be taken, but cannot be counted in reckoning the eight required majors. At least one course in Physical Chemistry and one in Organic Chemistry must be included in the courses taken if they have not been taken before.

Chemistry courses given in the Departments of Geology and Home Economics may be included in these eight majors.

The eighth major of graduate work will be devoted to specific preparation (in residence) for the dissertation, either in the laboratory (research) or in the library (historical work), under the direction of some instructor chosen by the candidate.

A course leading to the Master's degree in the Chemistry of Nutrition is given in the Department of Home Economics.

THE DEGREE OF BACHELOR OF SCIENCE

Chemistry may be taken as a major subject to fulfil the requirement for a principal sequence or as a minor subject to fulfil the requirement for a secondary sequence.

I. PRINCIPAL SEQUENCES

1) Course 2, 3 (or 2S, 3S), 4, 6, 7, 8, 20, and any other two courses in the Department except 1. If courses 33 and 34 or courses 30 and 31 be taken, course 4 is not required.

2) Combination with other science departments: By dropping the necessary majors from the latter portion of sequence 1) above, nine-major sequences may be offered involving the following courses: (1) three majors in College Physics, i.e., 3, 4, 5 (3S, 4S), but not 1, 2, preceding or accompanying six Chemistry courses enumerated in 1) above; (2) one to three majors in Geology selected from Geology 2, 3, 11, 12, 40–45, 50, 52, 53, when these courses follow Chemistry courses 2, 3 (or 2S, 3S), and 6; (3) two majors of Physiological Chemistry provided they are taken after courses 2, 3, (2S, 3S), 4, and 6 in Chemistry; (4) two majors in Chemistry of Foods and Dietetics, provided these courses follow 2, 3 (2S, 3S), 4, and 6 in Chemistry.

II. SECONDARY SEQUENCES

a) For students specializing in Physics: courses 2, 3, 6, 7, 8, and one major from courses 20, 21, 22.

b) For students specializing in Biological Science: courses 2, 3, 4, 6, 8, and one major from courses 20, 21, 22. If possible course 7 should also be taken.

c) For students specializing in Geology: courses 2, 3, 6, 7, 8, 9; the Department strongly advises courses 10, 14, and one major from courses 20, 21, 22.

SPECIAL STUDENTS

Special or unclassified students, not candidates for a degree, will be received, but in every case they will be required to give evidence, satisfactory to the instructors, that their previous training has been sufficient to enable them to derive full profit from the courses they propose to take.

PREPARATION FOR PROFESSIONAL WORK

I. PREPARATION FOR TEACHING

1. *University and College Positions.*—(*a*) For recommendations for major appointments in the larger universities and colleges only students who have taken the degree of Doctor of Philosophy will be considered to have had an adequate preparation. (*b*) For recommendations for chairs in Chemistry in smaller colleges at least the preparation demanded for the Master's degree will be required. (*c*) For recommendations for minor appointments in universities and colleges the work represented by the principal sequence of 9 majors in Chemistry required for the Bachelor's degree, supplemented by from three to eight majors of advanced work in Chemistry, will be considered an adequate preparation.

2. *Secondary Schools.*—The work represented by the principal sequence of 9 majors in Chemistry, required for the Bachelor's degree, is at present considered preparation for teaching in secondary schools. Some work in the College of Education is recommended. Men will find it advisable to be prepared also to teach Physics, Mathematics, or Geology. Women will find it wiser to combine Chemistry with Home Economics, Physics, Physiography, Physiology, Botany, or Zoölogy.

II. PREPARATION FOR TECHNICAL WORK

1. Thorough scientific training in all branches of chemistry required for the Doctor's degree forms the best preparation for a career as a chemical expert in any branch of chemical industry. With this preparation the principles and details of technical processes are quickly grasped, advances in industrial processes are intelligently followed, and newly discovered principles are readily applied.

All the more important requests received from technical establishments specify a doctorate of philosophy, with its training to do research work as a fundamental requirement.

2. Students who have taken from ten to fifteen majors of work in the Department are able to fill satisfactorily positions as assistants in technical and analytical laboratories and, after some practical experience, to advance to positions of independent responsibility. Students should take courses 1 to 10, inclusive, two majors in courses 13–19, and courses 21 and 22, in addition to course 20. If the student's work is primarily in Organic Chemistry, he should take, if possible, two or three courses selected from 30–32 and 35–37; if his work is in Inorganic Chemistry primarily, he should take courses 50–52. Students taking the fuller preparation outlined are given the preference in answering requests received by

the Department; but students with less complete training are also sought by technical firms for minor positions.

Work in Physics should supplement the work in Chemistry, and a knowledge of Bacteriology is often most helpful.

3. The Department gives, with other departments (notably Physics and Mathematics) of the University, and the Department of Manual Training of the University High School, the equivalent of three years of a four years' course in Chemical Engineering. Students are able to take a large part of this work in the purely scientific fundamental branches while they are candidates for a Bachelor's degree.

III. PREPARATION FOR GOVERNMENT WORK

1. For the more important government positions in Chemistry the doctorate of philosophy is demanded as an essential condition for candidacy.

2. For minor positions (e.g., Junior Chemist in the United States service) the Bachelor's degree is considered sufficient. The principal sequence in Chemistry, required for the degree, should be supplemented by *advanced* work in two or three branches of Chemistry (Inorganic, Organic, Physical, Analytical). If possible, the full 15 majors allowed by the University rules should be taken in the Department besides work in Elementary Physics, German, and French; a knowledge of Bacteriology is also helpful.

The Department does not pledge itself to secure positions for those who have carried out any one of the above recommended sets of courses; but, as a matter of fact, competent students find suitable places quickly, and in the past the demand for chemists has far exceeded the supply.

CHEMICAL SOCIETIES

The Kent Chemical Society is a club of students open to all those who have had six majors of Chemistry. The Society meets biweekly to listen to papers by members and others.

The Chicago Section of the American Chemical Society holds monthly meetings (except in summer) which the students of the University are welcome to attend. Membership in the Society is open to advanced students at special rates.

LABORATORY FEE

There is a laboratory fee of $5.00 per major for all courses involving laboratory work in the Department of Chemistry. A deposit of $5.00 for breakage is also required of each student.

COURSES OF INSTRUCTION

NOTE.—After course 9, the courses are arranged in groups according to subjects: courses 10–19 include courses in Analytical Chemistry, 25–49 in Organic Chemistry, 50–59 in Inorganic Chemistry, 60–74 in Physical Chemistry and Radioactivity; 80–89 are general in nature, and 90–101 are research courses. Nos. 75–79, 30–34, 40–43, and 608 are open to, and suitable for, Senior College students.

I. PRIMARILY FOR THE JUNIOR COLLEGES

1. Elementary General Chemistry: Inorganic I.[1]—Prerequisite: preparatory Physics. DM. Summer, First Term. Classroom, 6 hours a week; laboratory, 12 hours a week, MR. NASH. Mj. Autumn. Classroom, 3 hours a week; laboratory, 6 hours a week, ASSISTANT PROFESSOR TERRY AND MR. ———.

[1] Limited-credit course: After a student has credit for 18 majors but less than 27, these courses will be credited at one-half major each; after he has credit for 27 majors they will not be credited at all.

2. General Chemistry: Inorganic II (continuation of course 1).—Prerequisite: course 1. DM. Summer, Second Term, MR. NASH. Mj. Winter, ASSISTANT PROFESSOR TERRY AND MR. ———.

NOTE.—Course 2, Winter Quarter, is a continuation of course 1, but may be entered by those having credit for admission Chemistry.

3. General Chemistry: Inorganic III (continuation of course 2). Prerequisite: course 2. Mj. Spring, 1918, MISS WETTON.

NOTE.—Courses 1, 2, and 3 are consecutive courses. Separate credit is given for each, but students are advised not to take one course only. The aim of these courses is to give a definite idea of the fundamental principles of chemistry, and not to overburden the student with a mass of unconnected facts. The conception of chemical equilibrium and the modern theory of solutions are freely used. The lectures will be experimental to a considerable extent. The courses are designed to meet the wants, not only of those who wish to go deeper into chemistry, but of all who wish to study the science as part of a liberal education. The lectures and classroom work of 1, 2, and 3 may be taken by graduate students without the laboratory work or laboratory fee.

2S. General Chemistry: Inorganic (first course).—For students who have had preparatory Chemistry. Prerequisite: preparatory Chemistry and preparatory Physics, one unit each. DM. Summer, First Term. Classroom, 6 hours a week; laboratory, 12 hours a week, ASSISTANT PROFESSOR TERRY; Mj. Autumn. Classroom, 3 hours a week; laboratory, 6 hours a week, ASSISTANT PROFESSOR WENDT AND MISS WETTON.

3S. General Chemistry: Inorganic (continuation of course 2S).—DM. Summer, Second Term, ASSISTANT PROFESSOR TERRY; Mj. Winter, ASSISTANT PROFESSOR WENDT AND MISS WETTON.

NOTE.—Whenever, in exceptional cases, the preparation of a student in 2 or 2S justifies it, Qualitative Analysis may be substituted for 3 or 3S.

4. Elementary Organic Chemistry.—Prerequisite: course 3 or 3S. Classroom, 3 hours a week; laboratory, 6 hours a week (subject to change); Mj. Autumn, ASSISTANT PROFESSOR GLATTFELD; Spring, PROFESSOR STIEGLITZ AND MR. ———.

6. Qualitative Analysis (introductory course).—The lectures deal with the Chemistry of the analytical reactions, and special attention is given to the development and application of the laws of equilibrium and solutions. This course is, in an important sense, one in advanced General Chemistry. Classroom, 2 hours a week; laboratory, 8 or 16 hours a week. Prerequisite: course 3 or 3S. Mj. Summer and Autumn, ASSOCIATE PROFESSOR SCHLESINGER; Winter, ASSISTANT PROFESSOR TERRY; Spring, PROFESSOR STIEGLITZ.

7. Qualitative Analysis (continuation of course 6).—Mj. or DM. Summer and Autumn, ASSOCIATE PROFESSOR SCHLESINGER; Winter, ASSISTANT PROFESSOR TERRY; Spring, MR. ———.

NOTE.—Courses 6, 7, and 10 form a continuous course, which may be begun in any quarter. The aim of courses 6, 7, and 10 will be to train the student to do intelligent analytical work, based on a knowledge of the scientific principles of the subject, and to apply and amplify his knowledge of General and Physical Chemistry.

II. PRIMARILY FOR THE SENIOR COLLEGES

8. Quantitative Analysis (introductory course).—Chiefly laboratory work in gravimetric and volumetric analysis. Laboratory, 8 or 16 hours a week; lecture, 1 hour. Prerequisite: course 7. Medical students will be admitted to the course after having taken course 6. Mj. or DM. Summer, ASSISTANT PROFESSOR WENDT and MISS WALLEN; Autumn and Winter, ASSISTANT PROFESSOR WENDT AND MR. ———; Spring, ASSISTANT PROFESSOR GLATTFELD AND MR. ———.

8M. Quantitative Analysis.—A special course for premedical and medical students giving the elements of gravimetric and volumetric analysis. Prerequisite: course 6. Summer, either Term, ASSISTANT PROFESSOR WENDT; Autumn and Winter, ½Mj. ASSISTANT PROFESSOR WENDT AND MR. ———; Spring, ½Mj. ASSISTANT PROFESSOR GLATTFELD.

9. Quantitative Analysis (continuation of course 8).—Mj. or DM. Laboratory, 10 or 20 hours a week. Mj. Summer, Assistant Professor Wendt and Miss Wallen; Autumn and Winter, Assistant Professor Wendt and Mr. ———; Spring, Assistant Professor Glattfeld.

Note.—Courses 8 and 9 form a continuous course which may be begun in any quarter.

10. Advanced Qualitative Analysis (continuation of courses 6 and 7).—Open to Senior College students. Prerequisite: course 7. Mj. or DM. Laboratory, 10 or 20 hours a week. Summer and Autumn, Associate Professor Schlesinger; Winter and Spring, Assistant Professor Terry.

11. Theory of Quantitative Analysis.—½Mj. 2 lectures a week. Winter, Assistant Professor Wendt.

12–19. Special Methods in Quantitative Analys's.—

12. Standard Methods of Water Analysis	½Mj.
13. Standard Methods of Food Analysis	½Mj. or Mj.
14. Analysis of Iron, Steels, and Ferro-alloys	½Mj. or Mj.
16. Preparation and Analysis of Gases	½Mj.
17. Electrolytic Analysis, Gravimetric	½Mj.
18. Electrometric Titration	½Mj.
19. Advanced Rock and Mineral Analysis	Mj.

Summer, Assistant Professor Wendt; Autumn, Winter, Assistant Professor Wendt and Mr. ———; Spring, Assistant Professor Glattfeld and Mr. ———.

15. Organic Elementary Analysis.—½Mj. Summer, Assistant Professor Wendt; Autumn, Winter, and Spring, Associate Professor Piccard.

20. Elementary Physical Chemistry.—Mj. 3 hours lectures; 6 hours laboratory work. Prerequisite: course 8. Autumn, Professor Harkins.

21. Elementary Physical Chemistry (continuation of course 20).—Hours as in 20. Prerequisite: course 20 or its equivalent and Physics 3 and 4. Mj. Winter, Professor Harkins.

22. Elementary Physical Chemistry (continuation of course 21).—Hours as in 20. Prerequisite: course 21 or its equivalent. Spring, Professor Harkins.

25. Toxicology.—½Mj. Autumn, Professor Haines and Assistant.

26. Poisons and Their Detection.—A conference and laboratory course. M. Spring, Second Term, Professor Haines.

III. PRIMARILY FOR THE GRADUATE SCHOOL

30. Organic Chemistry.—Lectures, 2 hours a week; laboratory, 6 hours a week. Prerequisite: Qualitative Analysis and Elementary Organic Chemistry (course 4 or its equivalent). Mj. Autumn, Professor Stieglitz.

Note.—Students who have had adequate laboratory work in Organic Chemistry are admitted to the lectures of courses 30, 31, or 32 without payment of a laboratory fee.

31. Organic Chemistry (continuation of course 30).—Lectures, 3 hours a week; laboratory, 4 hours a week. Mj. Winter, Professor Stieglitz.

32. Organic Chemistry (continuation of course 31).—The Aromatic Series. Lectures, 2 hours a week; laboratory work, 4 hours a week. Prerequisite: course 31 (or course 4 for Medical and Home Economics students). Mj. Spring, Professor Stieglitz.

33. General Organic Chemistry.—Fatty and aromatic series. Lectures, 5 hours a week; laboratory work, 10 hours a week. Prerequisite: course 7. DM. First Term, Summer, Assistant Professor Glattfeld.

Note.—The lectures of courses 33 and 34 may be taken without the laboratory work and without payment of the laboratory fee by students who have had adequate laboratory work in Organic Chemistry.

34. General Organic Chemistry (continuation of course 33).—Prerequisite: course 33 or 4. DM. Second Term, Summer; same hours as course 33. Assistant Professor Glattfeld.

35. Organic Preparations.—Laboratory work, 10 or 20 hours a week. Prerequisite: courses 7 and 9, Organic Chemistry, and a reading knowledge of German. DM. Summer, First Term, PROFESSOR STIEGLITZ, Second Term, ASSISTANT PROFESSOR GLATTFELD; Mj. Autumn, Winter, Spring, ASSOCIATE PROFESSOR PICCARD.

36. Organic Preparations (continuation of course 35).—DM. Summer, First Term, PROFESSOR STIEGLITZ, Second Term, ASSISTANT PROFESSOR GLATTFELD; Mj. Autumn, Winter, and Spring, ASSOCIATE PROFESSOR PICCARD.

37. Organic Preparations (continuation of course 36).—DM. Summer, First Term, PROFESSOR STIEGLITZ, Second Term, ASSISTANT PROFESSOR GLATTFELD; Mj. Autumn, Winter, and Spring, ASSOCIATE PROFESSOR PICCARD.

NOTE.—Students who have taken the laboratory work of courses 30 and 31 or of courses 33 and 34 will omit course 35 and go on with course 36.

41. The Aromatic Series.—Lectures, 2 hours a week. Prerequisite: Organic Chemistry. ½Mj. Autumn, 1917, ASSOCIATE PROFESSOR PICCARD. [Not given in 1918–19; see course 32.]

42. The Carbohydrates and the Terpenes and Their Derivatives.—½Mj. PROFESSOR STIEGLITZ. [Not given in 1918–19.]

43. Organic Nitrogen Derivatives.—Uric-acid series, pyridine, quinoneimides, and phenazine compounds; a discussion of the alkaloids, ptomaines, and organic dyestuffs. Prerequisite: course 31. ½Mj. PROFESSOR STIEGLITZ. [Not given in 1918–19.]

44. Physical Chemistry Applied to Organic Problems.—Lectures, 2 hours a week. Prerequisite: courses 31 and 60, 61, or 62. ½Mj. PROFESSOR STIEGLITZ. [Not given in 1918–19.]

45A. Selected Topics of Organic Chemistry.—Reversibility; tautomerism; stereoisomerism; organic dyestuffs; application of the electron theory to organic compounds. Prerequisite: Organic Chemistry. M. First Term, Summer, PROFESSOR STIEGLITZ.

45B. Selected Topics of Organic Chemistry.—Prerequisite: Organic Chemistry. ½Mj. The subjects discussed will be selected from the field of chemistry of aromatic and cyclic compounds. ASSOCIATE PROFESSOR PICCARD. [Not given in 1918–19.]

46. Organic Dyes.—Prerequisite: The Aromatic Series. ½Mj. Winter, ASSOCIATE PROFESSOR PICCARD.

50. Inorganic Preparations.—Laboratory work, 10 or 20 hours a week; classroom work, 2 hours a week. Prerequisite: course 9 and a reading knowledge of German. Mj. or DM. Summer and Winter, ASSOCIATE PROFESSOR SCHLESINGER; Autumn, PROFESSOR HARKINS.

NOTE.—This course must be accompanied by course 54A in Summer and 55 in Winter.

51. Inorganic Preparations (continuation of course 50).—Mj. or DM. Same schedule as course 50.

52. Inorganic Preparations (continuation of course 51).—Mj. or DM. Same schedule as course 50.

54A. Selected Topics in Inorganic Chemistry.—Dicussions of selected topics in inorganic chemistry such as peroxides and related salts, complex salts, hydrates, molecular compounds, iso- and heteropoly acids, Werner's theory, allotrophy, etc. Lectures only. ½Mj. ASSOCIATE PROFESSOR SCHLESINGER. [Not given in 1918–19.]

54B. Selected Topics in Inorganic Chemistry.—Active hydrogen, nitrogen, oxygen, and chlorine; the passive state; Werner's theory, etc. ½Mj. Summer, ASSOCIATE PROFESSOR SCHLESINGER.

55. Advanced General Chemistry.—Discussions bearing chiefly upon the work of courses 50, 51, and 52, and relating to such subjects as temperature measurement, crystal form and habit, isomorphism, solid solution, double salts,

thermal analysis, alloys, transition temperatures, colloids, etc. This course is intended to supplement the work of the courses in inorganic preparations but can be taken independently. Prerequisite: same as for course 50. Lectures only. ½Mj. Winter, Associate Professor Schlesinger.

56. Special Topics in Inorganic Chemistry.—The subjects studied are the valence relations of the elements and the properties of the elements in selected groups of the periodic system. In 1915–16 the helium, the iron, and the rare earth groups were considered. ½Mj. Professor Harkins. [Not given in 1918–19.]

57. The Periodic System and the Interrelations of the Elements.—Lectures, ½Mj. Professor Harkins. [Not given in 1918–19.]

58. The Constitution of Liquids and Solids: Surface Tension and Colloids.—Lectures. ½Mj. Professor Harkins. [Not given in 1918–19.]

59. The Structure of Matter and the Molecular Theory as Applied to Organic Liquids and Solids.—Prerequisite: Physical Chemistry or College Physics, 3 majors. Lectures. ½Mj. Summer, Professor Harkins.

60S. Elementary Physical Chemistry.—Lectures, 3 hours a week; laboratory work, 6 hours. Prerequisite: course 8 and Physics 30. Mj. Summer, Professor Harkins.

63. Physico-chemical Measurements I.—Laboratory work, 10 or 20 hours a week. Prerequisite: course 22 or 60S and Physics 5. Mj. or DM. Summer, Autumn, Winter, and Spring, Professor Harkins.

64. Physico-chemical Measurements II.—Laboratory course. Continuation of course 63. Mj. or DM. Summer, Autumn, Winter, and Spring, Professor Harkins.

65. Theories of Solutions I.—½Mj. Professor Harkins. [Not given in 1918–19.]

66. Theories of Solutions II.—½Mj. Professor Harkins. [Not given in 1918–19.]

67. Selected Topics in Physical Chemistry.—This will be largely a course on the application of physical chemistry to definite problems. Lectures. ½Mj. Winter, Associate Professor Schlesinger. [Not given in 1918–19.]

68. Chemical Thermodynamics.—Prerequisite: Physical Chemistry and Calculus. ½Mj. Spring, Professor Harkins. [Not given in 1918–19.]

69. The Chemistry of Gas Reactions.—Prerequisite: Physical Chemistry and Calculus. ½Mj. Professor Harkins.

75. Radioactivity and the Subatomic Phenomena.—Lectures. Prerequisite: course 60. ½Mj. Summer, Assistant Professor Wendt.

76. Laboratory Course in Radioactivity.—To accompany or follow course 68. ½Mj. Spring and Summer, Assistant Professor Wendt.

79. Photo-Chemistry and Radio-Chemistry.—Lectures two hours a week, ½Mj. Spring, Assistant Professor Wendt.

82. Club Meetings.—Meetings of the Kent Chemical Society will be held twice a month. They may be attended by anyone interested. The subjects for the meetings will be announced at least one week in advance. Summer, Autumn, Winter, and Spring.

83. The Teaching of Chemistry.—A series of conferences. ½Mj. [Not given in 1918–19.]

85. The Chemistry and Preparation of Medicinal Drugs.—½Mj. Spring, Professor Haines.

90–96. Research Work (for the Ph.D. Degree).—These courses will include from 30 to 40 hours a week of laboratory work, under the special direction of some one of the instructors in the Department. It is expected that research work for

a Doctor's dissertation will require 4–6 quarters (4–6 DMjs.). Before being admitted to research a candidate must satisfy the instructors of the Department that his previous training has been sufficient.

90. Research in Organic and Physico-organic Chemistry.—DM. or 2DM. Summer, First Term; Mj. or DMj. Autumn, Winter, and Spring, PROFESSOR STIEGLITZ (with ASSISTANT PROFESSOR TERRY AND DR. ———).

91. Research in Physical Chemistry and Radioactivity.—Mj. or DMj. Summer, Autumn, Winter, and Spring, PROFESSOR HARKINS.

92. Research in Inorganic and Physical Chemistry.—Mj. or DMj. Summer, Autumn, and Winter, ASSOCIATE PROFESSOR SCHLESINGER.

93. Research in Organic Chemistry.—Mj. or DMj. Autumn, Winter, and Spring, ASSOCIATE PROFESSOR PICCARD.

95. Research in Organic Chemistry.—Summer, Autumn, and Spring, ASSISTANT PROFESSOR GLATTFELD.

96. Research in Radioactivity and Photo-Chemistry.—Mj. or DMj. Summer, Autumn, and Winter, ASSISTANT PROFESSOR WENDT.

97. Independent Research.—Summer, Autumn, Winter, and Spring. Mj

98. Masters' Dissertation in Qualitative Analysis.—Mj. Summer, Autumn, and Winter, ASSISTANT PROFESSOR TERRY.

98. Masters' Dissertation in Organic Chemistry.—Mj. Summer, Autumn, and Spring, ASSISTANT PROFESSOR GLATTFELD.

99. Masters' Dissertation in Quantitative Analysis.—Mj. Summer, Autumn, and Winter, ASSISTANT PROFESSOR WENDT.

100. Research in Mineralogical and Geological Chemistry.—Mj. Autumn, Winter, and Spring, ASSISTANT PROFESSOR BROKAW (Geology).

101. Research in the Chemistry of Food.—Mj. Summer, Autumn, and Winter, ASSISTANT PROFESSOR BLUNT (College of Education).

CHEMISTRY COURSES IN THE DEPARTMENT OF PHYSIOLOGICAL CHEMISTRY

(See the Biological Group Circular)

CHEMISTRY COURSES IN THE DEPARTMENT OF GEOLOGY

50. Industrial Geology.—A study of the more important industries in which raw materials of mineral origin are prepared for use. The course includes a brief treatment of the metallurgy of the common metals and a study of the manufacture of coke, cement, clay products, glass, petroleum products, etc. Field trips on Saturdays to plants in and near Chicago are supplemented by detailed reports on each plant. Expenses about $10.00. Classroom work 3 days a week. Prerequisite: Geology 2, 3, 5, or 12 and a working knowledge of Chemistry. Mj. ASSISTANT PROFESSOR BROKAW. [Not given in 1918–19.]

51. Petroleum and Coal.—An advanced course on petroleum and coal. The course includes a critical study of (1) the modern theories of origin, (2) the location, stratigraphy, and structure of the important fields of the world, (3) the methods of prospecting and exploiting the deposits, and (4) technology of oil and coal. Prerequisite: Geology 16. Desirable antecedent, Organic Chemistry. Mj. ASSISTANT PROFESSOR BROKAW. [Not given in 1918–19.]

52. Ore Deposits.—A discussion of the principles of ore deposition; the nature, distribution, and genesis of metalliferous ore deposits in the United States; a study of the relations of ore deposits to geological structure and of the changes which ore deposits undergo through processes conditioned by factors related to depth. The course includes laboratory work illustrating the uses of mine maps and the compilation of geologic cross-sections through mines. Prerequisite: Geology 12, 16, and 30, Chemistry 6, Mathematics 3. Desirable antecedents: Mathematics 5, Mechanical Drawing, and Geography 12. Mj. Winter, ASSISTANT PROFESSOR BROKAW.

53. Chemistry of Ore Deposits.—The course will include (1) a study of physical and chemical laws applied to geological problems, with special reference to the phenomena involved in the formation of ore deposits; (2) studies in paragenesis and the interpretation of paragenetic groups of minerals; (3) the study and critical interpretation of geologic and mining reports dealing with the origin of ore bodies. Prerequisite: Geology 40. Mj. Spring, ASSISTANT PROFESSOR BROKAW. [May not be given in 1918–19.]

54. Field Work in Mining and Mining Geology.—Students in Mining Geology are advised to spend some of their summers in mining camps where they may find employment as miners, mine samplers, assayers, draughtsmen, surveyors, etc. For the sake of experience it is desirable that they serve in as many different capacities as practicable. In many mining camps opportunity is offered for a study of General Geology, ore deposits, mining machinery, metallurgical works, etc. Frequent communication with the instructor is required, and when the work and reports are sufficiently thorough, credit will be given. Prerequisite: course 40. Summer, ASSISTANT PROFESSOR BROKAW.

CHEMISTRY COURSES IN THE DEPARTMENT OF HOME ECONOMICS

36. Chemistry of Food.—Study of the chemistry of fats, carbohydrates, proteins, as food constituents, with special emphasis upon the composition and nutritive value of such foods as meat, flour, milk, butter, etc. The laboratory is partly qualitative and partly quantitative. Prerequisite: Organic Chemistry. Laboratory fee, $3.00. Mj. Summer, Autumn, and Winter, ASSISTANT PROFESSOR BLUNT AND MISS MCKEE.

37. Chemistry of Food (continued).—A continuation of the work in course 36. The subject-matter may be adapted to the special needs of the students. Lecture and laboratory. For graduate or Senior College students. Prerequisite: Home Economics 36 or its equivalent. Laboratory fee, $3.00. Mj. Autumn, ASSISTANT PROFESSOR BLUNT AND MISS MCKEE.

38A. Nutrition.—A study of the processes of digestion and metabolism, and the nutritive requirements of the body, giving a scientific basis for the work in dietaries. The laboratory work consists chiefly of experiments on digestion and of qualitative and quantitative urine analysis in connection with special diets. Students may follow this course by either 39A or 38B, or both. Prerequisite: Home Economics 36. Laboratory fee, $1.50. M. Summer, First and Second Terms; Winter, First Term, ASSISTANT PROFESSOR BLUNT AND MISS ELIZABETH W. MILLER.

38B. Nutrition (continued).—A continuation of 38A. The course may include some study of pathological conditions in metabolism and a feeding or metabolism experiment. Laboratory fee, $1.50. M. Summer, Second Term, and Winter, Second Term, ASSISTANT PROFESSOR BLUNT.

39A. Dietaries.—A study of the food requirements of individuals as modified by age, sex, activity, etc., with special consideration given to the food of school children and institutional groups. The theory of infant feeding is included. Prerequisite: Home Economics 3 or 5 and 38A. Laboratory fee, $2.50. M. Summer and Winter, Second Term, 10:30–12:30, MISS ELIZABETH W. MILLER.

40. Readings in Nutrition.—Reading and discussion of some of the recent work on normal and abnormal nutrition. Prerequisite: Home Economics 38A and 39A or their equivalent. The consent of the instructor must be obtained before registering. M. Summer, Second Term; ½Mj. Winter, ASSISTANT PROFESSOR BLUNT AND MISS ELIZABETH W. MILLER.

DOCTORS OF PHILOSOPHY OF THE UNIVERSITY OF CHICAGO

MATHEMATICS

1896 Leonard Eugene Dickson, Professor of Mathematics, University of Chicago.
The Analytic Representation of Substitutions on a Power of a Prime Number of Letters with a Discussion of the Linear Group.

John Irwin Hutchinson, Professor of Mathematics, Cornell University, Ithaca, N.Y.
On the Reduction of Hyperelliptic Functions ($p=2$) to Elliptic Functions by a Transformation of the Second Degree.

1898 Herbert Ellsworth Slaught, Professor of Mathematics, University of Chicago.
The Cross-Ratio Group of 120 Quadratic Cremona Transformations of the Plane.

1899 John Anthony Miller, Professor of Mathematics and Astronomy, Swarthmore College, Swarthmore, Pa.
Concerning Certain Elliptic Modular Functions of Square Rank.

1900 Gilbert Ames Bliss, Professor of Mathematics, University of Chicago.
The Geodesic Lines on the Anchor Ring.

George Lincoln Brown, Professor of Mathematics, South Dakota Agricultural College, Brookings, S.D.
A Ternary Linear Substitution Group of Order 3·360.

William Gillespie, Professor of Mathematics, Princeton University, Princeton, N.J.
On the Reduction of Hyperelliptic Integrals ($p=3$) to Elliptic Integrals by Transformation of the Second and Third Degree.

Derrick Norman Lehmer, Associate Professor of Mathematics, University of California, Berkeley, Cal.
Asymptotic Evaluation of Certain Totient Sums.

John Hector McDonald, Assistant Professor of Mathematics, University of California, Berkeley, Cal.
On the System of a Binary Cubic and Quadratic and the Reduction of Hyperelliptic Integrals of Genus Two to Elliptic Integrals by a Transformation of the Fourth Order.

Ernest Brown Skinner, Assistant Professor of Mathematics, University of Wisconsin, Madison, Wis.
Ternary Monomial Substitution Groups of Finite Order with Determinant ± 1.

1901 William Findlay, Professor of Mathematics, McMaster University, Toronto, Ont.
The Sylow Subgroups of the Symmetric Group.

Thomas Milton Putnam, Associate Professor of Mathematics and Dean of the Lower Division, University of California, Berkeley, Cal.
The Quaternary Linear Homogeneous Group and the Ternary Linear Fractional Group.

1903 Oswald Veblen, Professor of Mathematics, Princeton University, Princeton, N.J.; Captain, Ordnance Reserve Corps.
A System of Axioms for Geometry.

1904 William Henry Bussey, Associate Professor of Mathematics, University of Minnesota, Minneapolis, Minn.
Generational Relations for the Abstract Group Simply Isomorphic with the Group LF(2; p^n).

Herbert Edwin Jordan, Assistant Professor of Mathematics, University of Kansas, Lawrence, Kan.
Group Characters of Various Linear Groups.

Arthur Whipple Smith, Associate Professor of Mathematics, Colgate University, Hamilton, N.Y.
Symbolic Treatment of Differential Geometry.

1905 Thomas Emory McKinney, Professor of Mathematics and Astronomy, University of South Dakota, Vermilion, S.D.
Concerning a Certain Type of Continued Fractions Depending on a Variable Parameter.

Robert Lee Moore, Assistant Professor of Mathematics, University of Pennsylvania, Philadelphia, Pa.
Sets of Metrical Hypotheses for Geometry.

1906 William Raymond Longley, Assistant Professor of Mathematics, Yale University, New Haven, Conn.
A Class of Periodic Orbits of an Infinitesimal Body Subject to the Attraction of n Finite Bodies.

Arthur Ranum, Assistant Professor of Mathematics, Cornell University, Ithaca, N.Y.
The Group of Classes of Congruent Matrices with Application to the Group of Isomorphisms of Any Abelian Group.

Anthony Lispenard Underhill, Assistant Professor of Mathematics, University of Minnesota, Minneapolis, Minn.; Captain, C.A.O.R.C., Fort Constitution, New Castle, N.H.
Invariants under Point Transformations in the Calculus of Variations.

Buzz M. Walker, Professor of Mathematics and Director of School of Engineering, Mississippi Agricultural and Mechanical College, Agricultural College, Miss.
On the Resolution of Higher Singularities of Algebraic Curves into Ordinary Double Points.

1907 George David Birkhoff, Assistant Professor of Mathematics, Harvard University, Cambridge, Mass.
Asymptotic Properties of Certain Ordinary Differential Equations, with Applications to Boundary Value and Expansion Problems.

Robert Lacey Börger, Professor of Mathematics, Ohio University, Athens, Ohio.
On the Determination of Ternary Linear Groups in the Galois Field of Order p^2.

Louis Ingold, Assistant Professor of Mathematics, University of Missouri, Columbia, Mo.
Vector Interpretation of Symbolic Parameters.

Nels Johann Lennes, Professor of Mathematics, University of Montana, Missoula, Mont.
Curves in Non-metrical Analysis Situs with an Application in the Calculus of Variations.

Frederick William Owens, Assistant Professor of Mathematics, Cornell University, Ithaca, N.Y.
The Introduction of Ideal Elements and Construction of Projective n-space in Terms of a Planar System of Points.

1907 Norman Richard Wilson, Professor of Mathematics, University of Manitoba, Winnipeg, Canada; on leave of absence on military service, Lieutenant, Artillery Corps, B.E.F.
Isoperimetrical Problems Which Are Reducible to Non-isoperimetrical Problems.

1908 Mary Emily Sinclair, Associate Professor of Mathematics, Oberlin, College, Oberlin, Ohio.
On a Compound Discontinuous Solution Connected with the Surface of Revolution of Minimum Area.

1909 Thomas Buck, Instructor in Mathematics, University of California, Berkeley, Cal.
Oscillating Satellites near the Lagrangian Equilateral Triangular Points.

Arnold Dresden, Assistant Professor of Mathematics, University of Wisconsin, Madison, Wis.
The Second Derivatives of the Extremal-Integral.

Harris Franklin MacNeish, Instructor in Mathematics, DeWitt Clinton High School, New York, N.Y.
Linear Polars of the k-hedron in n-space.

1910 Richard Philip Baker, Assistant Professor of Mathematics and Acting Head of the Department, State University of Iowa, Iowa City, Iowa.
The Problem of the Angle-Bisectors.

William Hunt Bates, Associate Professor of Mathematics, Purdue University, La Fayette, Ind.
An Application of Symbolic Methods to the Treatment of Mean Curvatures in Hyper-Space.

Theophil Henry Hildebrandt, Assistant Professor of Mathematics, University of Michigan, Ann Arbor, Mich.
A Contribution to the Foundations of Fréchet's Calcul Fonctionnel.

Egbert J. Miles, Assistant Professor of Mathematics, Yale University, New Haven, Conn.
The Absolute Minimum of a Definite Integral in a Special Field.

Anna Johnson Pell, Assistant Professor of Mathematics, Mount Holyoke College, South Hadley, Mass.
I. Biorthogonal Systems of Functions. II. Application to the Theory of Integral Equations.

Arthur Dunn Pitcher, Professor of Mathematics, Western Reserve University, Cleveland, Ohio.
The Interrelation of Eight Fundamental Properties of Classes of Functions.

Marion Ballantyne White, Dean of Women and Professor of Mathematics, State Normal School, Ypsilanti, Mich.
The Dependence of the Focal Point on Curvature in Space Problems of the Calculus of Variations.

1911 Lloyd Lyne Dines, Professor of Mathematics, University of Saskatchewan, Saskatoon, Canada.
The Highest Common Factor of a System of Polynomials, with an Application to Implicit Functions.

Theodore Lindquist, Professor of Mathematics, State Normal School, Emporia, Kan.
Mathematics for Freshman Students of Engineering.

Ralph Eugene Root, Professor of Mathematics, U.S. Naval Academy, Annapolis, Md.
Interated Limits in General Analysis.

1911 Albert Harris Wilson, Associate Professor of Mathematics, Haverford College, Haverford, Pa.
The Canonical Types of Nets of Quadratic Forms in the Galois Field of Order p^n.

1912 Edward Wilson Chittenden, Instructor in Mathematics, University of Illinois, Urbana, Ill.
Infinite Developments and the Composition Property $(K_{12}B_1)_*$ in General Analysis.

Charles Albert Fischer, Instructor in Mathematics, Columbia University, New York, N.Y.
Some Contributions to the Theory of Functions of Lines.

Charles Thompson Sullivan, Assistant Professor of Mathematics, McGill University, Montreal, Canada.
Properties of Surfaces Whose Asymptotic Lines Belong to Linear Complexes.

1913 William Charles Krathwohl, Assistant Professor of Mathematics, Armour Institute of Technology, Chicago, Ill.
Modular Invariants of Two Pairs of Cogredient Variables.

Wilson Lee Miser, Assistant Professor of Mathematics, University of Arkansas, Fayetteville, Ark.
On Linear Homogeneous Differential Equations with Elliptic Function Coefficients.

Frank Marion Morrison, Sometime Associate Professor of Mathematics, University of Washington, Seattle, Wash.
On the Relation between Some Important Notions of Projective and Metrical Differential Geometry.

Elton James Moulton, Assistant Professor of Mathematics, Northwestern University, Evanston, Ill.
On Figures of Equilibrium of a Rotating Heterogeneous Fluid Body.

†Mildred Leonora Sanderson.
Formal Modular Invariants with an Application to Binary Modular Covariants.

1914 Myer Grupp Gaba, Instructor in Mathematics, Cornell University, Ithaca, N.Y.
A Set of Postulates for General Projective Geometry of n Dimensions.

Harold Reynolds Kingston, Instructor in Mathematics, University of Manitoba, Winnipeg, Canada.
Metric Properties of Nets of Plane Curves.

William Vernon Lovitt, Assistant Professor of Mathematics, Purdue University, La Fayette, Ind.
A Type of Singular Points for a Transformation of Three Variables.

Forbes Bagley Wiley, Professor of Mathematics, Denison University, Granville, Ohio.
Proof of the Finiteness of Modular Covariants of a System of Binary Form of Cogredient Points.

1915 Allen Fuller Carpenter, Assistant Professor of Mathematics, University of Washington, Seattle, Wash.
Ruled Surfaces Whose Flecnode Curves Have Plane Branches.

Charles Ross Dines, Instructor in Mathematics, Dartmouth College, Hanover, N.H.
Functions of Positive Type and Selected Topics in General Analysis.

Jasper Ole Hassler, Instructor in Mathematics, Crane Junior College, Chicago, Ill.
Plane Nets Periodic of Period Three under the Laplace Transformation.

† Deceased, October 15, 1914.

1915 Olive Clio Hazlett, Associate in Mathematics, Bryn Mawr College, Bryn Mawr, Pa.
On the Classification and Invariantive Characterizations of Nilpotent Algebras.

Archibald Henderson, Professor of Mathematics, University of North Carolina, Chapel Hill, N.C.
The Twenty-seven Lines upon the Cubic Surface.

Alfred Lewis Nelson, Instructor in Mathematics, University of Michigan, Ann Arbor, Mich.
Plane Nets with Equal Laplace-Darboux Invariants.

Vincent Collins Poor, Instructor in Mathematics, University of Michigan, Ann Arbor, Mich.
A Certain Type of Exact Solution of the Equations of Motion of a Viscous Liquid.

Samuel Watson Reaves, Professor of Mathematics, University of Oklahoma, Norman, Okla.
Metric Properties of Flecnodes on Ruled Surfaces.

Mary Evelyn Wells, Instructor in Mathematics, Vassar College, Poughkeepsie, N.Y.
The Determination of All Inequalities of Certain Types in General Linear Integral Equation Theory.

Chester Henry Yeaton, Assistant Professor of Mathematics, Northwestern University, Evanston, Ill.; Aërological Service, Signal Corps, Richmond, Me.
Surfaces Characterized by Certain Properties of Their Directrix Congruences.

1916 Elmer Daniel Grant, Assistant Professor of Mathematics, Michigan School of Mines, Houghton, Mich.
The Motion of a Flexible Cable in a Vertical Plane.

Arthur McCracken Harding, Professor of Mathematics, University of Arkansas, Fayetteville, Ark.
On Certain Loci Projectively Connected with a Given Plane Curve.

William Leroy Hart, Lieutenant, First Training Company, Fort Monroe Training Camp, Fort Monroe, Va.
Differential Equations and Implicit Functions in Infinitely Many Variables.

Gillie Aldah Larew, Adjunct Professor of Mathematics, Randolph–Macon Woman's College, Lynchburg, Va.
Necessary Conditions for the Problem of Mayer in the Calculus of Variations.

Arthur Shepard Merrill, Assistant Professor of Mathematics, University of Montana, Missoula, Mont.
An Isoperimetric Problem with Variable End-Points.

Arthur Richard Schweitzer, Chicago, Ill.
Les Idées directrices de la logique génétique des mathématiques.

David Melville Smith, Assistant Professor of Mathematics, Georgia School of Technology, Atlanta, Ga.
Jacobi's Condition for the Problem of Lagrange in the Calculus of Variations.

Pauline Sperry, Instructor in Mathematics, University of California, Berkeley, Cal.
Properties of a Certain Projectively Defined Two Parameter Family of Curves on a General Surface.

1917 Jacob Millison Kinney, Teacher of Mathematics, Hyde Park High School, Chicago.
The General Theory of Congruences without Any Preliminary Integration.

1917 Kenneth Worcester Lamson, Instructor in Mathematics, Columbia University, New York, N.Y.
A General Implicit Function Theorem, with an Application to Problems of Relative Minimum.

Flora Elizabeth Le Stourgeon, Head of the Department of Mathematics, Liggett School for Girls, Detroit, Mich.
Minima of Function of Lines.

James Elijah McAtee, Intructor in Mathematics, William Jewell College, Liberty, Mo.
Modular Invariants of a Quadratic Form for a Prime Power Modulus.

Thomas McNider Simpson, Jr., Assistant Professor of Mathematics, University of Texas, Austin, Tex.
Relation between the Metric and Projective Theories of Space Curves.

William Pinkerton Ott, Instructor in Mathematics, University of Nashville, Nashville, Tenn.
The General Problem of the Type of the Brachistochrone with Variable End-Points.

Levi Stephen Shively, Professor of Mathematics, Mount Morris College, Mount Morris, Ill.
A New Basis for the Metric Theory of Congruences.

MATHEMATICAL ASTRONOMY

1900 Forest Ray Moulton, Professor of Astronomy, University of Chicago.
Periodic Oscillating Satellites.

1903 William Albert Hamilton, Professor of Astronomy, Beloit College, Beloit, Wis.
The True Radii of Convergence for Expansions as Power Series in the Time, in the Case of Parabolic Motion.

1904 Arthur Constant Lunn, Associate Professor of Applied Mathematics, University of Chicago.
The Differential Equations of Dynamics.

1905 Delonzo Tate Wilson, Assistant Professor of Mathematics, Case School of Applied Science, Cleveland, Ohio.
Work on Minor Planets.

1906 Frank Loxley Griffin, Professor of Mathematics, Reed College, Portland, Ore.
Certain Periodic Orbits of k Finite Bodies Revolving about a Relatively Large Central Mass.

1908 William Duncan MacMillan, Assistant Professor of Astronomy, University of Chicago.
Periodic Orbits about an Oblate Spheroid.

1909 Herbert Earle Buchanan, Professor of Mathematics, University of Tennessee, Knoxville, Tenn.
Periodic Oscillations of Three Finite Masses about the Langrangian Circular Solutions.

1911 Daniel Buchanan, Assistant Professor of Mathematics, Queen's University, Kingston, Ont.
A Class of Periodic Solutions of the Problem of Three Bodies, Two of Equal Mass, the Third Moving on a Straight Line.

1913 Lloyd Arthur Heber Warren, Assistant Professor of Mathematics, University of Manitoba, Winnipeg, Canada.
A Class of Asymptotic Orbits in the Problem of Three Bodies.

1915 John William Campbell, Lecturer in Mathematics, Wesley College, Winnipeg, Canada.
Periodic Solution of the Problem of Three Bodies in Three Dimensions.

Louis Allen Hopkins, Instructor in Mathematics, University of Michigan, Ann Arbor, Mich.
On the Theory of the Motion of the Small Planets with a Periodic Orbit for the Hilda Type.

PRACTICAL ASTRONOMY AND ASTROPHYSICS

1913 Curvin Henry Gingrich, Assistant Professor of Astronomy, Carleton College, Northfield, Minn.
A Determination of the Photographic Magnitudes of Comparison Stars in Certain Hagen Fields.

Oliver Justin Lee, Instructor in Practical Astronomy, Yerkes Observatory, Williams Bay, Wis.
The Spectroscopic System 9 Camelopardalis.

1914 Frank Craig Jordan, Assistant Professor of Astronomy, University of Pittsburgh.
The Color-Changes of Certain Variable Stars of Short Periods.

1915 Harlan True Stetson, Instructor, Students' Astronomical Laboratory, Harvard University, Cambridge, Mass.
On the Apparatus and on Methods for Thermoelectric Measurements in Photographic Photometry, with Application to the Determination of Magnitude, Spectral Intensities, and the Light Curves of Variable Stars.

1917 Edwin Powell Hubble, Captain, 343d Infantry, Camp Grant, Rockford, Ill.
Photographic Investigations of Faint Nebulae.

PHYSICS

1897 Gordon Ferry Hull, Professor of Physics, Dartmouth College.
On the Use of the Interferometer in the Study of Electric Waves.

Isabel Stone, Principal of American School for Girls, Rome, Italy.
On the Electrical Resistance of Thin Films.

1898 Edwin Sheldon Johonnott, Associate Professor of Physics, Rose Polytechnic Institution.
Thickness of the Black Spot in Liquid Films.

1899 Henry Gordon Gale, Professor of Physics, University of Chicago.
On the Relation between Density and Index of Refraction of Air.

1900 Robert Francis Earhart, Professor of Physics, Ohio State University.
The Sparkling Potentials between Plates at Small Distances.

1901 Fritz Reichmann, Practical Physicist, Troy, N.Y.
The Capacities of Air Condensers for Very Small Distances between the Plates.

1902 Frank Baldwin Jewett, Chief Engineer, Western Electric Co., New York, N.Y.
A New Method of Determining the Vapor-Density of Metallic Vapors.

1904 Thomas Eaton Doubt, Associate Professor of Physics, Armour Institute of Technology, Chicago, Ill.
The Effect of Intensity upon the Velocity of Light.

Fannie Cornelia Frisbee (Mrs. Frank B. Jewett), New York City, N.Y.
The Effects of Pressure on Magnetic Induction.

1904 Thomas Carlyle Hebb, Professor of Physics, State Normal School, Marquette, Mich.
The Velocity of Sound.

1905 Frederic Lendhall Bishop, Professor of Physics, University of Pittsburgh, Pittsburgh, Pa.
The Thermal Conductivity of Lead.

Glenn Moody Hobbs, Secretary of the American School of Correspondence, Chicago, Ill.
The Relation between P.D. and Spark-Length for Small Values of the Latter.

Carleton John Lynde, Professor of Physics, MacDonald College, Quebec, Canada.
The Effect of Pressure on Surface Tension.

1906 William Richard Blair, Director Government Observatory, Mount Weather, Va.
The Change of Phase Due to the Passage of Electric Waves through Thin Films.

Lawrence Emery Gurney, Assistant Professor of Physics, University of the Philippines, Manila, P.I.
The Viscosity of Water at Low Rate of Shear.

1907 Oliver Charles Clifford, Associate Professor of Electrical Engineering, Armour Institute of Technology, Chicago, Ill.
Susceptibility of Copper and Tin and Their Alloys.

George Winchester, Professor of Physics, Washington and Jefferson College, Washington, Pa.
Discharge of Electricity from Metals under the Influence of Ultra-Violet Light.

1909 William Ross Ham, Professor of Physics, Pennsylvania State College, State College, Pa.
The Polarization of Primary X-Rays.

Charles Albert Proctor, Assistant Professor of Physics, Dartmouth College, Hanover, N.H.

The Variation of $\frac{e}{m}$ with Speed in the Case of Cathode Rays.

Newland Farnsworth Smith, Professor of Physics, Central College, Danville, Ky.
Effect of Tension on Thermal and Electrical Conductivity.

1910 Louis Begeman, Professor of Physics, Iowa State Teachers College.
The Determination of "E" by the Cloud Method.

J. Harry Clo, Professor of Physics, Tulane University, New Orleans, La.
The Effect of Temperature upon the Ionization of Gas.

Ansel Alphonso Knowlton, Professor of Physics, Reed College, Portland, Ore.
Preparation and Testing of Heusler Alloys.

John Mathias Kuehne, Associate Professor of Physics, University of Texas, Austin, Tex.
The Electrostatic Effect of a Changing Magnetic Field.

James Remus Wright, Associate Professor of Physics, University of the Philippines, Manila, P.I.
Photo-electric Effects of Aluminum as a Function of the Wave-Length of the Incident Light.

1911 Harold De Forest Arnold, Research Laboratory, Bell Telephone Company, New York.
Limitations Imposed by Slip and Inertia Terms upon Stokes Law for the Motion of Spheres through Liquids.

1911 †Edwin Sherwood Bishop, Instructor in Physics, University High School, University of Chicago.
A Determination of the Minimum Ionizing Kinetic Energy of an Electron in a Gas.

Harvey Fletcher, Research Laboratory, Bell Telephone Co., New York, N.Y.
A Verification of the Theory of Brownian Movements and a Direct Determination of the Value of Ne for Gaseous Ionization.

Harvey Brace Lemon, Assistant Professor of Physics, University of Chicago.
The Influence of Temperature upon the Intensities of the Lines of the Hydrogen Spectrum.

Howard Wilson Moody, Professor of Physics, Mississippi Agricultural College, Agricultural College, Miss.
A Determination of the Ratio of the Specific Heats and the Specific Heat at Constant Pressure of Air and Carbon Dioxide.

1913 Lachlan Gilchrist, Instructor in Physics, University of Toronto.
An Absolute Determination of the Viscosity of Air.

Edward James Moore, Associate Professor of Physics, Oberlin College, Oberlin, Ohio.
Reaction Effects Produced by the Discharge of Electricity from Points in Gases and the Bearing of These Effects on the Theory of the Small Ion.

1914 Albert Edward Hennings, Assistant Professor of Physics, University of Saskatchewan, Saskatoon, Canada.
A Study of the Contact Potentials and Photo-electric Properties of Metals *in Vacuo*.

Verne Frank Swaim, Assistant Professor of Physics, Bradley Polytechnic Institute, Peoria, Ill.
The Pressure-Shift of Lines in the Spectrum of Zinc.

1915 William Henry Kadesch, Instructor in Physics, U.S. Naval Academy, Annapolis, Md.
The Energy of Photo-Electrons from Sodium and Potassium as a Function of the Frequency of the Incident Light.

John Yui-Bong Lee, 520 Alin Street, Oakland, Cal.
The Determination of "E" by the Small-Drop Method Using Solid Spheres.

Isaiah March Rapp, Instructor in Physics, University of Oklahoma, Norman, Okla.
The Flow of Air through Capillary Tubes.

Oscar William Silvey, Instructor in Physics, Purdue University, La Fayette, Ind.
A Comparison of the Fall of a Droplet in a Liquid and in a Gas.

1916 Arthur Jeffrey Dempster, Instructor in Physics, University of Chicago.

Ertle Leslie Harrington, Instructor in Physics, University High School, University of Chicago.
A Redetermination of the Absolute Value of the Coefficient of Viscosity of Air.
The Properties of Slow Canal Rays.

Yoshio Ishida, Assistant in Physics, University of Chicago.
The Kinetic Theory of Rigid Molecules.

Leonard B. Loeb, The Bureau of Standards, Washington, D.C.
Mobility of Gaseous Ions in High Electric Fields.

† Deceased.

1916 Carl Danforth Miller, The Westinghouse Research Laboratory, Pittsburgh, Pa.
Absorption Coefficients of Soft X-Rays.

Benjamin Estill Shackelford, The Westinghouse Company, New York, N.Y.
Temperature and Blackening Effects in Helical Tungsten Filaments.

William Henry Souder, Physicist at Bureau of Standards, Washington, D.C.
The Normal Photo-electric Effect of Lithium, Sodium, and Potassium as a Function of Wave-Lengths and Incidental Energy.

Walter Ticknor Whitney, Claremont, Cal.
The Pole Effect in a Calcium Arc.

1917 Karl Kelchner Darrow, Bell Telephone Co., New York, N.Y.
Preliminary Report on a New Method for Determining the Velocity of Sound in Gases.

Victor Hugo Gottschalk.
The Nature of the Process of Ionization by Alpha Rays.

Leopold Joseph Lassalle, Department of Physics, Pennsylvania State College, State College, Pa.
The Law of Fall of a Sphere through Carbon Dioxide and an Exact Determination of the Viscosity of That Gas.

Margaret Calderwood Shields, Department of Physics, Mount Holyoke College, South Hadley, Mass.
A Determination of the Ratio of the Specific Heats of Hydrogen at 18 Degrees and −190 Degrees.

CHEMISTRY

1894 Adolph Bernhard, State Normal School, La Crosse, Wis.
Ueber die Einführung von Acylen in den Benzoylessigaether.

Warren Rufus Smith, Professor and Head of the Department of Chemistry, Lewis Institute, Chicago, Ill.
On the Addition Products of the Aromatic Isocyanides.

1896 Bernard Conrad Hesse, Consulting Chemist, General Chemical Co., New York City.
On Malonic Nitrile and Some of Its Derivatives.

Samuel Ellis Swartz, Professor of Chemistry and Physics, Fairmount College, Wichita, Kan.
The Action of Sodium Ethylate on Amide Bromides.

1897 James Bert Garner, Research Chemist, Mellon Institute of Industrial Research, Pittsburgh, Pa.
Condensations with Benzoin by Means of Sodium Ethylate.

Lauder William Jones, Professor and Head of the Department of Chemistry, University of Cincinnati, Cincinnati, Ohio.
On Salts of Nitroparaffine and Acylated Derivatives of Hydroxylamine.

1898 Frank Burnett Dains, Professor of Chemistry, University of Kansas, Lawrence, Kan.
On the Isourea Ethers and Other Derivatives of Ureas.

Otto Folin, Hamilton Kuhn Professor of Biological Chemistry, Harvard University, Cambridge, Mass.
On Urethanes Medical School, Boston, Mass.

Elizabeth Jeffreys, Professor of Chemistry, Pritchett College, Glasgow, Mo.
On Undecylamine and Pentadecylamine and the Preparation of the Higher Amines of the Aliphatic Series.

1898 Herbert Newby McCoy, Carnotite Reduction Co., Lindsay Light Co., Chicago, Ill.
On the Hydrochlorides of Carbo-phenylamido Derivatives.

1899 John Charles Hessler, Professor of Chemistry and Dean of James Millikin University, Decatur, Ill.
On Alkyl Malonic Nitriles and Their Derivatives.

William McPherson, Professor and Head of the Department of Chemistry and Dean of the Graduate School, Ohio State University, Columbus, Ohio; Major, U.S.A., Chemical Adviser, Trench Warfare Section, Ordnance Department.
On the Nature of the Oxyazo Compounds.

James Harvey Ransom, Professor of General Chemistry, Purdue University, La Fayette, Ind.
On the Molecular Rearrangement of o-Aminophenylethyl Carbonate to o-Oxyphenylurethane.

1900 Henry Chalmers Biddle, Associate Professor of Chemistry, University of California.
Ueber Derivate des Isuretins, der Formhydroxamsäure und ihre Beziehungen zur Knallsäure.

1901 Ralph Harper McKee, Director of Research Laboratory, Tennessee Copper Co., Ridgewood, N.J., and Associate Professor of Chemical Engineering, Columbia University, New York, N.Y.
On the Oxygen Ethers of the Ureas: Methyl- and Ethylisourea.

1902 Solomon Farley Acree, Research Chemist, National Wood Chemical Association, Syracuse, N.Y.
On Sodium Phenyl and the Action of Sodium on Ketones.

Wallace Appleton Beatty, New York, N.Y.
The Action of Carbon Monoxide on Sodium Alcoholates Alone and in the Presence of Salts of Fatty Acids.

Eugene Paul Schoch, Professor of Chemistry, University of Texas, Austin, Tex.
The Red and the Yellow Mercuric Oxides and the Mercuric Oxychlorides.

Edwin Emery Slosson, Literary Editor of *The Independent*, New York City.
On Acylhalogenamine Derivatives and the Beckmann Rearrangement.

1903 Henry Tabor Upson, President and Treasurer, Pease Oil Co., Buffalo, N.Y.
The Molecular Rearrangement of Aminophenylalkyl Carbonates.

1904 Maxwell Adams, Professor of Chemistry, University of Nevada, Reno, Nev.
On Some Hydroxylamine Compounds.

Raymond Foss Bacon, Director of the Mellon Institute of Industrial Research, University of Pittsburgh, Pittsburgh, Pa.; Lieutenant Colonel, American Expeditionary Forces, U.S.A., Commanding Chemical Service Unit, France.
On the Reactions of Sodium Benzhydrol.

William McAfee Bruce, Manager, Eastern Arkansas Demonstration Farm, Blackton, Ark.
On the Oxygen Ethers of Urea.

Nellie Esther Goldthwaite, Kobe College, Kobe, Japan.
On Substituted Benzhydrol Derivatives and Bromcyanacetic Ether.

Oswin W. Willcox, Chief Chemist and Superintendent, Aetna Explosives Co., Mount Union, Pa.
On the Reactions of Ethyl Chlorsulphonate.

1905 William Lloyd Evans, Professor of Chemistry, Ohio State University, Columbus, Ohio; Captain, Ordnance Officers' Reserve, Chief Chemist, Gunpowder Reservation Laboratory.
On the Behavior of Benzyol Carbinol toward Alkalies and Oxidizing Agents.

William McCracken, Professor of Natural Sciences, State Normal School, Kalamazoo, Mich.
Studies in Caralysis. V. The Catalysis of Imidoesters.

Hermann Schlesinger, Associate Professor of Chemistry, University of Chicago.
Studies in Catalysis. VI. The Catalysis of Imidoesters.

1906 Roy Hutchinson Brownlee, Director, American Carbo-Hydrogen Products Co., Pittsburgh, Pa.
On Precipitated Sulphur.

Charles M. Carson, Professor and Head of the Department of Chemistry, Houghton School of Mines, Houghton, Mich.
On Amorphous Sulphur: Further Study of the Two Forms of Liquid Sulphur as Dynamic Isomers.

Henry Max Goettsch, Assistant Professor of Technical Chemistry, University of Cincinnati, Cincinnati, Ohio.
The Absorption Coefficients of Uranium Compounds.

Willis Stose Hilpert, The Miner Laboratories, Chicago, Ill.
Stereoisomeric Chlorimido Acid Esters.

James Wright Lawrie, Chief Chemist and Manager for Jobbins & Co., Aurora, Ill.
The Chemistry of the Acetylidene Compounds.

Andrew Fridley McLeod, Instructor in Chemistry, Beloit College, Beloit, Wis.
On Aldol, Pentaerythrose, and the Action of Copper Acetate on the Hexosés.

1907 †Edith Ethel Barnard
The Catalysis of Imidoesters as Affected by the Presence of Non-Electrolytes and Electrolytes.

Katherine Blunt, Assistant Professor of Home Economics, University of Chicago.
The Formation of Amidines.

Willey Denis, Research Assistant, Harvard Medical School, Cambridge, Mass.
On the Behavior of Various Aldehydes, Ketones, and Alcohols toward Oxidizing Agents.

Robert Anderson Hall, Lieutenant, Infantry, American Expeditionary Forces, U.S.A., France.
The Action of Ammonia on Isourea Esters.

Louis Allen Higley, Professor of Chemistry, New Mexico College of Agriculture and Mechanical Arts, State College, N.M.
On the Behavior of Sodium and Sodium Alcoholates toward Various Esters.

William Horace Ross, Research Chemist, Bureau of Soils, Department of Agriculture, Washington, D.C.
On the Relation between the Radioactivity and the Composition of Thorium and Uranium Minerals.

Louis A. Test, Associate Professor of Chemistry, Iowa State College, Ames, Iowa.
The Rearrangement of o-Amino Phenyl Esters.

† Deceased.

1908 George Cromwell Ashman, Professor of Chemistry, Bradley Institute, Peoria, Ill.
Studies in Radioactivity.

1909 Ernest Anderson, Associate Professor of Chemistry, Massachusetts State Agricultural College, Amherst, Mass. [on leave of absence]; Professor of Agricultural Chemistry, Transvaal University College, Pretoria, Transvaal.
The Action of Fehling's Solution on *d*-Galactose.

William Weldon Hickman, Professor of Chemistry, Assuit College, Assuit, Egypt.
The Catalysis of Imidoesters.

Winford Lee Lewis, Assistant Professor of Chemistry, Northwestern University, Evanston, Ill.; Captain, U.S.R., Ordnance Department, Trench Warfare Section, Washington, D.C.

Peter Powell Peterson, Head of the Department of Soils in the College of Agriculture, University of Idaho, Moscow, Idaho.
Stereoisomerism of Chlorimido-Ketones.

Lemuel Charles Raiford, Professor of Chemistry, Oklahoma Agricultural and Mechanical College, Stillwater, Okla.
Chlorimido Quinones.

Herman Augustus Spoehr, Chemical Plant Physiologist, Carnegie Institution, Tucson, Ariz.
The Behavior of the Ordinary Hexoses toward Hydrogen Peroxide in the Presence of Alkaline Hydroxides as Well as of Various Iron Salts.

1910 Emma Perry Carr, Professor and Head of the Department of Chemistry, Mount Holyoke College, Mount Holyoke, Mass.
The Aliphatic Imidoesters.

Elbert Edwin Chandler, Professor of Chemistry, Occidental College, Los Angeles, Cal.
Ionization Constants of the Second Hydrogen Ion of Dibasic Acids.

Ira Harris Derby, Assistant Professor of Chemistry, University of Minnesota, Minneapolis, Minn.
Studies in Catalysis of Imidoesters, IV.

Stewart Joseph Lloyd, Professor and Head of the Department of Chemistry and Metallurgy, University of Alabama, University, Ala.
Studies in Radioactivity.

Alan W. C. Menzies, Professor of Chemistry, Princeton University, Princeton, N.J.
Studies in Vapor-Pressure.

John Colin Moore, Instructor in Chemistry, Lake View High School, Chicago, Ill.
The Action of Water on Acyl Isoureas.

William Cabler Moore, Director of Research Laboratory, National Carbon Co., Cleveland, Ohio.
Studies in Organic Amalgams.

Fred Wilbert Upson, Professor and Head of the Department of Chemistry, University of Nebraska, Lincoln, Neb.
On the Action of Normal Barium Hydroxide on d. Glucose and d. Galactose.

1911 Thomas Bruce Freas, Associate Professor of Chemistry, Columbia University, New York, N.Y.
A Study of Thermostats.

John Foote Norton, Assistant Professor of Bacteriology, University of Chicago.
Simultaneous Reactions in Amidine Formation.

1911 HARLAN LEO TRUMBULL, Assistant Professor of Chemistry, University of Washington, Seattle, Wash.; Lieutenant, U.S.A., Ordnance Department, Washington, D.C.
The Molecular Rearrangement of Acid Chloramides and the Ionization of Their Salts.

LEROY SAMUEL WEATHERBY, Professor of Chemistry, University of Southern California, Los Angeles, Cal.
The Salt-Effects of the Nitrates and Sulphonates in the Catalysis of Imidoesters.

FRANKLIN LORINZO WEST, Professor of Chemistry, Utah Agricultural College, Provo, Utah.
The Physical and Chemical Properties of Organic Amalgams.

1912 PAUL DAVID POTTER, Chief Chemist, Sprague, Warner & Co., Chicago, Ill.
The Hydrates of Arsenic Pentoxide.

CHARLES HERMAN VIOL, Chief Chemist, Standard Chemical Co., Pittsburgh, Pa.
The Chemical Properties and Relative Activities of the Radio-Products of Thorium.

1913 GEORGE OLIVER CURME, JR., Assistant Professor of Chemistry, University of Pittsburgh, and Research Chemist, Mellon Institute of Industrial Research, Pittsburgh, Pa.
The Thermal Decomposition of the Symmetrical Diaryl-Hydrazines.

JOHN WILLIAM EDWARD GLATTFELD, Assistant Professor of Chemistry, University of Chicago.
The Oxidation of *d*-Glucose in Alkaline Solution by Air as Well as by Hydrogen Peroxide.

PAUL NICHOLAS LEECH, Research Chemist, American Medical Association.
The Molecular Rearrangement of Triaryl Methyl Hydroxylamines; a New Interpretation for the Rearrangement of Ketoximes.

ETHEL MARY TERRY, Assistant Professor of Chemistry, University of Chicago.
The Velocity Coefficient of Saponification of Ethyl Acetate.

1914 HAROLD STANARD ADAMS, Research Biochemist and Superintendent, Chemical Plant of Squibbs & Sons, New Brunswick, N.J.
Studies in Overvoltage.

ARTHUR WESLEY MARTIN, Professor of Chemistry and Physics, University of Nanking, Nanking, China.
Studies on Solutions in Anhydrous Formic Acid.

AGNES FAY MORGAN, Assistant Professor of the Chemistry of Nutrition, University of California, Berkeley, Cal.
I. Viscosities of Various Methyl and Ethyl Imidobenzoates and of the Sodium Salts of Para and Meta Nitrobenzoyl-chloroamides in Moderately Concentrated Aqueous Solutions. II. The Molecular Rearrangement of Some Triaryl Methylchloroamines.

HARRY MORRILL PAINE, Research Chemist, Drug and Dyestuffs Corporation, New York, N.Y.
The Effects of Salts on the Solubility of Other Salts: 1. The Solubility Relations of a Very Soluble Bi-univalent Salt. 2. The Ionization of Bi-bivalent Salts.

HARLEY MARTIN PLUM, Assistant Professor of Chemistry, Agricultural College, University of Nebraska, Lincoln, Neb.
The Extraction and Separation of the Radioactive Constituents of Carnotite.

BERT ALLEN STAGNER, Research Chemist, Mellon Institute of Industrial Research, Pittsburgh, Pa.
On the Molecular Rearrangements of Triarylmethyl Hydroxylamines.

1914 Clare Chrisman Todd, Professor of Chemistry, Washington Agricultural College, Pullman, Wash.
The Action of Alkaline Hydrogen Peroxide on d. Galactose.

1915 Clifford Daniel Carpenter, Associate Professor of Chemistry, Teachers College, Columbia University, New York City.
The Addition Compounds of Organic Substances with Sulphuric Acid.

Oscar Fred Hedenburg, Research Chemist, Mellon Institute of Industrial Research, Pittsburgh, Pa.
On the Esters, as well as the Monomolecular β- and γ-Lactones of d-Mannonic and d-Gluconic Acids; On Ortho Bis-d-Galactonic Acid, d-Galactonic γ-Lactone and Its Mono-Hydrate.

Edmund Charles Humphery, Chemist, E. I. du Pont de Nemours Co., Wilmington, Del.
Surface Tension at the Interface between Two Liquids.

Townes Randolph Leigh, Professor of Chemistry, Georgetown College, Georgetown, Ky.
On Chlorimido Esters and Chlorimido Benzil.

Edwin Daniel Leman, Research Chemist, Carnotite Reduction Co., Chicago, Ill.
The Relation between the Alpha-Ray Activities and Ranges of Radioactive Substances.

Helen Tredway (Mrs. Evarts A. Graham), Mason City, Iowa.
The Thermal Decomposition of Diaryl Hydrazines.

Ernest Dana Wilson, Research Chemist, Mellon Institute of Industrial Research, Pittsburgh, Pa.
The Structure of Complex Atoms.

1916 Groves Howard Cartledge, Professor of Chemistry, Davidson College, Davidson, N.C.
A Study of the Emanation Method of Determining Thorium.

Clyde Coleman, Research Chemist, Ault & Wiborg Co, Cincinnati, Ohio.
Further Studies on the Behavior of the Alkali Metal Formates in (Anhydrous) Formic Acid.

Ralph Edwin Hall, Research Chemist, Geo-physical Laboratory, Carnegie Institution, Washington, D.C.; Captain, U.S.A., Ordnance Department.
The Periodic System and the Properties of the Elements. The Free Energy of Dilution. The Freezing-Point Lowerings of Some Salts of Various Types of Ionization and of Salt Mixtures.

Lawrence Melvin Henderson, Instructor in Chemistry, The University of Minnesota, Minneapolis, Minn.; Lieutenant, U.S.A., Rockford, Ill.
The Ratio of Mesothorium to Thorium in Minerals.

William Tudor Pearce, Assistant Professor of Chemistry, North Dakota Agricultural College, Agricultural College, N.D.
Ionization and Solubility Relations of Salts of Higher Types, Intermediate Ions in Solutions of Unibivalent Salts and of Lanthanum Iodate, a Triunivalent Salt. II, Solubilities of Very Soluble Higher Type Salts.

Willard Allen Roberts, Instructor in Chemistry, Iowa State College, Ames, Iowa; Inspector, Signal Corps, U.S.A.
Studies on the Cobalt-Ammines.

Stanley Davis Wilson, Assistant Professor of Chemistry, Union Medical College, Peking, China.
The Effect of Added Salts upon the Velocity of Saponification of Ethyl Acetate by Sodium Hydroxide.

1917 Lester Aronberg, Research Chemist, Western Electric Co., Chicago, Ill.
The Spectrum of the Isotopes of the Lead. The Structure of the Bismuth Line $x = 4722$A.

Ralph Lyman Brown, Lieutenant, Chemistry Service, American Expeditionary Forces, France.
The Molecular Rearrangement of Sym. Di-triphenylmethylhydrazine.

Sidney Marsh Cadwell, Research Chemist, Federal Dyestuff and Chemical Co., Kingsport, Tenn.
The Beckmann Rearrangement: Determinations of Minute Quantities of Gold.

Earl Claudius Hamilton Davies, Assistant Professor of Chemistry, Missouri School of Mines, Rolla, Mo.
The Orientation of Molecules in the Surface of Liquids, the Energy Relations at Surfaces, Solubility, Adsorption, Emulsification, Molecular Association, and the Effects of Acids and Bases on Interfacial Tension.

Adeline Mae De Sale, Instructor in Chemistry, Lawrence College, Appleton, Wis.
The Velocity of Rearrangement of Benzoylazid.

Milton Theodore Hanke, Research Instructor, Sprague Memorial Institute, University of Chicago.
The Oxidation of Maltose in Alkaline Solutions by Hydrogen Peroxide and by Air. The Preparation and Study of Maltobionic Acid.

Frank Hynes Reed, Chemist, Sherwin Williams & Company, Chicago, Ill.
Studies in Conductivity. (A) Some Common Errors in the Determination of the Conductivity of Solutions. (B) The Behavior of Mixtures of Two Salts Containing a Common Ion, in Anhydrous Formic Acid Solutions.

James Kuhn Senior, Research Chemist, Rockefeller Institute, New York City; Lieutenant, Chemical Service Division, U.S.A.
Molecular Rearrangements in the Triarylmethylazide and Triarylmethylhydrazine Series.

Herbert Johnson Smith, Associate Professor of Chemistry, Mississippi Agricultural and Mechanical College, Agricultural College, Miss.
Solubility Products of Carbonates.

Ralph Kempton Strong, Professor of Chemical Engineering, Oregon Agricultural College, Corvallis, Ore.
Mesothorium-One and Radium: Their Isotopism and Enrichment.

William De Garmo Turner, Assistant Professor of Chemistry, School of Mines, University of Missouri, Rolla, Mo.
The Diffusion of Gases and the Density of Chlorine. A Search for Possible Isotypes of Chlorine.

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MATHEMATICS, ASTRONOMY AND ASTROPHYSICS, PHYSICS CHEMISTRY

1919

THE UNIVERSITY OF CHICAGO PRESS
CHICAGO, ILLINOIS

CALENDAR FOR THE YEAR 1919–20

1919

June 8	Sunday	Convocation Sunday
June 9	Monday	College Day
June 10	Tuesday	Summer Convocation
June 11	Wednesday	Examinations for the Spring Quarter
June 12	Thursday	
June 13	Friday	
June 13	Friday	Spring Quarter ends
June 14	Saturday	Registration for the Summer Quarter
June 16	*Monday*	*Summer Quarter begins*
June 16–21		Examinations of the College Entrance Examination Board
July 4	Friday	Independence Day: a holiday
July 12	Saturday	Special Examinations for removal of deficiencies (work reported conditioned or incomplete) incurred during the last quarter of residence
July 22	Tuesday	Examinations for the First Term of the Summer Quarter
July 23	Wednesday	
July 23	Wednesday	First Term of the Summer Quarter ends
July 24	Thursday	Second Term of the Summer Quarter begins
Aug. 24	Sunday	Convocation Sunday
Aug. 28	Thursday	Examinations for the Second Term of the Summer Quarter
Aug. 29	Friday	
Aug. 29	Friday	Autumn Convocation Second Term of the Summer Quarter ends
Sept. 1–6		Examinations for Admission
Sept. 29	Monday	Registration for the Autumn Quarter
Sept. 30	Tuesday	
Sept. 30	Tuesday	Special Examinations for all students returning for the Autumn Quarter, who incurred deficiencies (work reported conditioned or incomplete) in the last quarter of residence
Oct. 1	*Wednesday*	*Autumn Quarter begins: all classes meet*
Nov. 27	Thursday	Thanksgiving Day: a holiday
Dec. 21	Sunday	Convocation Sunday
Dec. 19	Friday	Examinations for the Autumn Quarter
Dec. 22	Monday	
Dec. 23	Tuesday	
Dec. 23	Tuesday	Winter Convocation, Autumn Quarter ends

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Jan. 2	*Friday*	*Winter Quarter begins*
Jan. 24	Saturday	Special Examinations for removal of deficiencies (work reported conditioned or incomplete) incurred during the last quarter of residence
Feb. 12	Thursday	Lincoln's Birthday: a holiday
Mar. 14	Sunday	Convocation Sunday
Mar. 16	Tuesday	Spring Convocation
Mar. 17	Wednesday	Examinations for the Winter Quarter
Mar. 18	Thursday	
Mar. 19	Friday	
Mar. 19	Friday	Winter Quarter ends
Mar. 20–28		Quarterly Recess
Mar. 29	*Monday*	*Spring Quarter begins*
April 24	Saturday	Special Examinations for removal of deficiencies (work reported conditioned or incomplete) incurred during the last quarter of residence
May 7, 8		Annual Conference with Co-operating Schools
June 13	Sunday	Convocation Sunday
June 14	Monday	College Day
June 15	Tuesday	Summer Convocation
June 16	Wednesday	Examinations for the Spring Quarter
June 17	Thursday	
June 18	Friday	
June 18	Friday	Spring Quarter ends

OFFICERS OF ADMINISTRATION

Harry Pratt Judson, President of the University, Harper Memorial Library, Room W11.

Ernest DeWitt Burton, Director of the University Libraries, Harper Memorial Library, Room M27.

Walter A. Payne, University Recorder and University Examiner, Cobb Lecture Hall, Room 5A.

David Allan Robertson, Secretary to the President, Harper Memorial Library, Room W13.

James Rowland Angell, Dean of the Faculties of Arts, Literature, and Science, Cobb Lecture Hall, Room 6A.

Albion Woodbury Small, Dean of the Graduate School of Arts and Literature, Cobb Lecture Hall, Room 6A.

Rollin D. Salisbury, Dean of the Ogden Graduate School of Science, Cobb Lecture Hall, Room 6A.

Marion Talbot, Dean of Women, Cobb Lecture Hall, Room 14A.

Leon Carroll Marshall, Dean of the Senior Colleges and Dean of the School of Commerce and Administration, Cobb Lecture Hall, Room 6B.

Robert Morss Lovett, Dean of the Junior Colleges, Cobb Lecture Hall, Room 9A.

Henry Gordon Gale, Dean in the Colleges of Science, Cobb Lecture Hall, Room 7A.

Horatio Hackett Newman, Dean in the Colleges of Science, Cobb Lecture Hall, Room 10A.

Percy Holmes Boynton, James Weber Linn, Ellis Hall; Wellington Downing Jones, Cobb Lecture Hall, Room 8A; Frank Justus Miller, Edith Foster Flint, Elizabeth Wallace, Deans inJunior Colleges.

Sophonisba Preston Breckinridge, Assistant Dean of Women, Lexington Hall.

Nathaniel Butler, Director of Co-operation with Secondary Schools; Dean of University College, Cobb Lecture Hall, Room 11A.

GENERAL INFORMATION

The organization of the University includes: the Graduate School of Arts and Literature; the Ogden Graduate School of Science; the Colleges (Senior, last two years, and Junior, first two years) of Arts, Literature, and Science; the Divinity School, the Law School, Courses in Medicine, the School of Education, the School of Commerce and Administration.

Faculty and equipment.—The faculty (exclusive of assistants) numbers three hundred and forty-four; the libraries contain 545,890 volumes and 200,000 pamphlets (estimated). The University owns nearly one hundred acres of land in Chicago and has forty buildings.

Location of the University.—The University grounds lie on both sides of the Midway Plaisance between Washington and Jackson parks, six miles south of the center of Chicago. Electric cars, elevated trains, and the Illinois Central suburban service reach all railway stations. Mail and baggage service is provided at the Information Office of the University.

The University year is divided into quarters: the Autumn (October, November, December); the Winter (January, February, March); the Spring (April, May, to the middle of June); the Summer (from the middle of June, July, August). For the year 1919–20 the exact dates for the opening of the four quarters are: Summer Quarter, June 16, 1919; Autumn Quarter, October 1, 1919; Winter Quarter, January 2, 1920; Spring Quarter, March 29, 1920. Students are admitted at the opening of each quarter; graduation exercises are held at the close of each quarter.

The unit of work and of credit is a *major*, i.e., a course of instruction involving four or five recitations or lecture hours per week for a full quarter, or double that number of hours for a term of six weeks. A *minor* is one-half a major. Normal work is three majors per quarter, or nine per year of three quarters.

Degrees.—The University confers in the Graduate Schools the degrees of Doctor of Philosophy and of Master of Arts and of Science; in the Colleges, the degrees of Bachelor of Arts, of Science, and of Philosophy; in the Divinity School, the degrees of Bachelor of Divinity, of Master of Arts, and of Doctor of Philosophy; in the Law School, the degrees of Doctor of Law and of Bachelor of Laws; in the School of Education, the degrees of Bachelor of Arts in Education, of Philosophy in Education, and of Science in Education; in the School of Commerce and Administration, the degree of Bachelor of Philosophy.

Fellowships, scholarships, student service, etc.—By virtue of endowments and special appropriations, fellowships and scholarships and service afford stipends or tuition to a number of able and deserving students. The University also maintains a bureau for securing outside employment.

Guests of the University.—Under certain conditions (see p. 7) Doctors of Philosophy of the University of Chicago, and of other universities, will be welcomed by the President as guests of the University.

FEES FOR MATRICULATION, TUITION, ETC.

A. *Matriculation fee.*—The matriculation fee is $5.00, and is required of every student on entrance into the University.

B. *Tuition fee.*—1. The tuition fee for new students in the Colleges, the School of Commerce and Administration, and the School of Education, including also unclassified students, is:

One major, $25.00.
Two or three majors, $50.00.
Each additional major above three, $15.00.

For those students who have been registered in the above-mentioned groups prior to the Summer Quarter, 1917, the tuition fee will remain as heretofore, $40.00 for two or three majors, $20.00 for a single major, and for each additional major over three, $15.00.

2. *All tuition and laboratory fees are due on or before the first day of each quarter, and are payable without extra fee up to the end of the fifth day of the quarter. All fees are payable to the Cashier,* Press Building, Room 1.

C. *Fines, etc.*—For failure to pay tuition fees within the first five days of the quarter a fee of $5.00 is added to the bill.

D. *Laboratory fee.*—Students in most laboratory courses pay a laboratory fee of $5.00 a major (M. or DMj. courses will be charged in proportion). In the Departments of Home Economics and Household Art, Modeling and Ceramics, and Manual Training, laboratory fees varying from $1.50 to $6.00 are charged for certain courses, depending on the nature of the courses. Ten dollars ($10.00) is the maximum charge for laboratory work in any one department. In addition to the regular laboratory fee, students in Chemistry will procure a coupon ticket, entitling them to $5.00 worth of laboratory material. Students doing laboratory work in the Departments of Zoölogy, Anatomy, Physiology, Botany, Pathology, and Hygiene and Bacteriology are required to purchase a laboratory supply and breakage ticket ($5.00 for a single course and $10.00 for more than one course in this group of departments) at the office of the Cashier, and file the same at the laboratory supply store, Room 10, Botany Building. New tickets must be purchased at the opening of each quarter, and a refund of the unused balance on the old tickets can be obtained at that time.

E. *A small materials fee* is charged in certain courses in Political Economy and Sociology.

F. *Gymnasium locker fee.*—For the use of a locker in the dressing-room of the gymnasium a fee of $1.00 a quarter is charged. A small fee is also charged for the use of the tennis courts.

G. *Graduation fee.*—The general graduation fee, including diploma, is $10.00. The graduation fee for Doctors of Philosophy, including diploma and hood, is $15.00. In the case of students taking the certificate of a two years' course the charge is $5.00.

ROOMS, BOARD, AND GENERAL EXPENSES

There are ten residence halls in the University quadrangles. Two of these are reserved for the students of the Divinity School, and five are for women. A University House is organized in each hall; each House has a Head, appointed by the President of the University, and a House Committee, elected by the members; also a House Counselor, selected from the Faculties of the

University by the members of the House. The membership of the House is determined by election, and each House is self-governing under the general control of the University.

The cost of rooms in the halls is from $25.00 to $75.00 per quarter of twelve weeks. This includes heat, light, and care. Each hall for women has separate dining-hall and parlors. The cost of table board in these halls is $5.50 per week.

The increasing cost of foods and service has rendered it necessary to increase the rate of board from $4.50, the figure at which it has been maintained for several years, to $5.50 per week in the residence halls for women. It is doubtful whether the rate of $5.50 per week will fully recompense the University for the higher costs. It is hoped, however, that the price of foods will not go any higher, but rather will become lower, thus enabling the University to reduce the price as soon as circumstances warrant.

All applications for rooms, or for information concerning rooms and board within the quadrangles, should be made to the Cashier.

The table shown below will furnish an estimate of the annual expenses, exclusive of tuition and laboratory fees, for thirty-six weeks of a student in the University residing within the quadrangles.

	Lowest	Average	Liberal
Rent and care of room	$ 60.00	$105.00	$225.00
Board	162.00	198.00	240.00
Laundry	18.00	30.00	45.00
Textbooks and stationery	10.00	20.00	50.00
Total	$250.00	$353.00	$560.00

An opportunity to share in co-operative housekeeping and thereby to reduce living expenses somewhat is offered at Drexel House, which accommodates sixteen women who share in the preparation of meals and the care of the house. The cost of room rent for each student is $25.00 for the quarter, and the co-operative plan makes the cost of table board considerably less than is possible under other circumstances. Some experience in housekeeping and adaptability to group life are necessary. Correspondence with reference to rooms in Drexel House should be addressed to the Director of the Housing Bureau.

The University of Chicago maintains its Housing Bureau in order to assist its students in finding the best accommodations obtainable in the University neighborhood. All rooms listed have been inspected and certain standards are maintained. Rooms on small inclosed courts are not listed, and all householders registered must rent exclusively to men or exclusively to women. The use of a reception room at least two evenings a week must be provided for women students. Students are asked to co-operate by insisting on these requirements even if they do not engage their rooms through the Housing Bureau. Upon arrival at the University, students should apply at once to the Housing Bureau for a list of rooms. Incoming students are especially cautioned against strangers who approach them at the station or on the streets and offer their services in securing rooms.

Most students off the quadrangles secure furnished rooms, which may be had at prices ranging from $30 to $60 a quarter, and take their meals at the University or at restaurants in the neighborhood. It is difficult to find good board by the week or month, and there are very few places where board and room are offered. As a result, it is customary to pay for each meal separately. Cafeteria service is provided at the University Commons—Ida Noyes Hall for women and Hutchinson Hall for men. Men occasionally find a small room, or a dark room, for less than $30 a quarter, but women usually have to pay $36 or more. Householders usually prefer men, hence the price level is higher for women. Not less than $4 a week should be allowed for table board, and one can seldom find a room with outside light, droplight, a study table, ample closet space, and a comfortable bed for less than $36 a quarter.

Desirable furnished rooms for light housekeeping are difficult to find. They range in price from $16 to $30 a month. In the University neighborhood there are very few two- or three-room apartments with private bath, and their rental unfurnished is from $30 a month up. The so-called kitchenettes in the vicinity of the University are small, usually dark, rooms with a kitchen table and gas plate, but never with running water. Rooms with kitchen privileges are to be had at the regular room rates with an additional charge of about $6 per quarter.

Furnished rooms or apartments of from four to ten rooms vary in price from $30 to $150 per month.

Lists of rooms may be obtained at the office, Room 1, Press Building, about one week before the opening of each quarter. Lists should be obtained in person at this office. Renting by mail is not satisfactory and students are advised against it.

DOCTORS OF PHILOSOPHY AS GUESTS OF THE UNIVERSITY

The President of the University, on recommendation of a Head of a Department, will welcome Doctors of Philosophy of the University of Chicago, as well as of other universities, as guests of the University, with the privilege of attending seminars and of carrying on research in the laboratories and libraries. There will be no charge except for laboratory supplies, and a nominal laboratory fee where laboratory work is done. Arrangements should be made in advance with the President of the University.

FELLOWSHIPS AND SCHOLARSHIPS

The Trustees appropriate annually the amount of twenty-two thousand one hundred and forty dollars ($22,140) for Fellowships in the Graduate Schools of Arts, Literature, and Science. These Fellowships range in value from $120, the tuition fees of a graduate student for three quarters, to $520, that is, $400 in addition to the tuition fees for three quarters. A limited number of Scholarships, covering a part or all of the tuition fees for three quarters, are also awarded annually.

Candidates for these Fellowships and Scholarships should send to the Deans of the Graduate Schools a record of their previous work and distinctions, degrees, and past courses of study, with copies of their written or printed work in the field of the department in which application is made. Applications must be received at the Deans' offices *not later than March 1 of each year*, in order to be considered for the following year. Appointments will be made April 1.

Fellows may be called upon for assistance in teaching in the University, or for kindred work; but in no case will they be expected or permitted to devote so much time to this work as to prevent the successful prosecution of their own work as students. Fellows will not engage in outside work for compensation, unless by permission of the President. Except in rare cases, students will not be appointed to Fellowships until they have done at least one year of graduate work.

In addition to the Scholarships mentioned above, one graduate Scholarship, yielding a sum sufficient to pay the annual tuition fees, is annually awarded to the best student in each department graduated from the University of Chicago during the preceding year.

A Scholarship yielding the amount of the tuition fees for three quarters is awarded annually in each department offering Junior College work to the student of highest rank in that department receiving the Associate's title during the preceding year.

Full particulars concerning higher degrees, Fellowships, Scholarships, and other matters of interest to graduate students will be found in the *Circular of Information* of the Colleges and Graduate Schools, which will be sent upon application.

AID TO STUDENTS

Besides Fellowships and Scholarships various kinds of assistance are offered to those who need help, under the following heads: Prizes, University Service, Loans by the Students' Fund Society, and Outside Employment. The position of the University in a large city brings the decided advantage of providing many opportunities for employment. Through the University Employment Bureau many students are able to secure all of the outside employment for which they have time. For further details applicants should send for the circular *Assistance to Students at the University of Chicago.*

DEGREES

Graduate study may lead to a Master's or to a Doctor's degree under the conditions specified below:

I. THE MASTER'S DEGREE

Two degrees are conferred, viz., *Master of Arts* and *Master of Science.*

1. *Candidacy.*—Any member of the Graduate Schools who has been in attendance one quarter or more, and whose undergraduate course is equivalent to that required for a corresponding Bachelor's degree in the University of Chicago,[1] and whose thesis subject has been accepted by the department concerned, may, on recommendation by the department or departments in which he is working, be enrolled, by vote of the Faculties of the Graduate Schools, as a candidate for a Master's degree. Application for admission to candidacy must be made on the blank provided for the purpose. This blank must be obtained by the applicant at the Dean's office, and the application must be on file in that office at least two months before the degree is conferred.

[1] Attention is particularly called to the fact that the term "equivalent" in this connection refers to quantity only. It does not affect the question of the specific Master's degree (Arts or Science) to which a given student's work would lead. In case the candidate did not obtain his Bachelor's degree at the University of Chicago, he will present to the Examiner on blanks furnished for the purpose a detailed statement of his undergraduate work. The Examiner cannot always report upon these statements during the opening week of the quarter.

2. *Requirements.*—Students thus accepted as candidates will be given a Master's degree on fulfilment of the following requirements:

a) At least three quarters' residence at the University.

b) At least 8 majors of graduate work at the University of Chicago. These 8 majors need not be all in one department, but must be selected according to some rational plan approved by the Deans of the Graduate Schools at least six months before the degree is conferred. The individual courses must receive the approval of the heads of the departments concerned.

c) A satisfactory dissertation on a subject approved by one of the departments in which the work is done.[1] The subject of the dissertation must be approved by the head of the department at least three months before graduation, and the dissertation in complete form must be submitted to the Department at least four weeks before the degree is conferred. This period may be lengthened to six weeks at the option of any department.

d) The delivery of five printed or typewritten copies of the dissertation to the University Library at least one week before the Convocation at which the degree is to be conferred. One of the copies must be bound.

e) A satisfactory examination on the work taken for the degree.

f) No course completed with a grade below C will count toward the Master's degree.

II. THE DEGREE OF DOCTOR OF PHILOSOPHY

The degree of *Doctor of Philosophy* is given, not on the basis of the completion of a certain amount of time spent upon a specified program, but as the recognition and mark of high attainments and ability in the candidate's chosen province, shown, first, by the production of a dissertation evincing the power of independent investigation and forming an actual contribution to existing knowledge; and, secondly, by the passing of examinations covering the general field of the candidate's subjects, with more detail in the case of the principal subject, with less detail in the case of the secondary subject or subjects.

1. *Candidacy.*—Any member of the Graduate Schools who has been in attendance one quarter or more, whose undergraduate course is equivalent to that required for a Bachelor's degree in the University of Chicago,[2] whose thesis subject has been accepted by the principal department, and who has a reading knowledge of two modern languages other than English, may, on recommendation by the principal department in which he wishes to take his degree, be enrolled, by vote of the Faculties of the Graduate Schools, as a candidate for the Doctor's degree. The languages other than English must be languages which contain important critical literature of the subject in which the candidate's principal work is done. They must be selected with the approval of the department of principal work and of the Dean, and a reading knowledge of the languages must be certified by the appropriate departments, not less than one academic year (9 months) before the degree is conferred. Application for admission to candidacy must be made on the blank provided for the purpose.

[1] In exceptional cases the Deans, upon the recommendation of the departments concerned, may accept an additional major in lieu of the dissertation.

[2] In case the candidate did not obtain his Bachelor's degree at the University of Chicago, he will present to the Examiner on blanks furnished for the purpose a detailed statement of his undergraduate work. The Examiner cannot always report upon these statements during the opening week of the quarter.

This blank must be obtained by the applicant at the Dean's office, and the application must be on file in that office before the close of the quarter preceding that in which the degree is conferred.

2. *Requirements.*—Students accepted as candidates will be given the Doctor's degree on fulfilment of the following requirements:

a) At least three years of resident work in pursuance of an accepted course of study. The student may follow one of two plans. Plan I: The work offered in fulfilment of the requirements for the Ph.D. degree in any department is outlined by the Department and approved by the Dean, for each candidate, not later than the first quarter of his last year of residence work. The work required will include such courses in departments allied to that of principal work as may be deemed necessary by the principal department to obviate narrow specialization. The work is selected with regard to the needs of the individual student, with the double purpose (1) of giving him a knowledge of the relations of his principal subject to cognate branches of learning, and (2) of preparing him for productive scholarship. All courses offered in fulfilment of the requirement for the degree must be advanced courses, and a list of courses shall be submitted to the Faculties when the applicant is admitted to candidacy. Plan II: Under this plan the work offered must include one principal and either one or two secondary subjects. The amount of work required in the secondary subject or subjects is normally 9 majors. Candidates for the degree of Doctor of Philosophy may not, under this plan, take more than two-thirds of their work in one department, and may not take work which is to count toward the degree in more than three departments.

b) A satisfactory final examination on the work done in preparation for the degree.

c) The presentation of a satisfactory dissertation upon a subject which has been approved by the Head of the Department in which the principal part of the candidate's work has been done.

d) A good command of literary expression and such knowledge of subjects considered fundamental as may be prescribed by the several departments.

3. *Dissertation.*—Each student is required to prepare a dissertation upon some topic connected with his principal subject. The dissertation must constitute an actual contribution to knowledge. Its subject must be submitted for approval to the Head of the Department at least twelve months before the date of the final examination. The dissertation itself must be submitted to the Head of the Department at least one month before the date of the final examination. This period may be lengthened to six weeks at the option of any department.

One week before the Convocation at which the degree is conferred, a typewritten copy of the dissertation, together with a certificate signed by the Head or acting Head of the Department that the copy, as submitted, is accepted for publication as the candidate's dissertation for the Doctor's degree, shall be filed in the office of the Deans of the Graduate Schools. Said copy may not be withdrawn from the office of the Deans of the Graduate Schools until the required one hundred copies are deposited in the Library.

The candidate shall deposit in the office of the Deans of the Graduate Schools a contract in legal form to the effect that he will furnish the General Library with one hundred copies (including two bound in half-roan) which shall fulfil in

format, cover, title-page, and stock all the University requirements. (See special circular entitled *Dissertation Regulations*.)

Any one of the following three methods may be followed:

a) A signed statement may be filed in the Graduate Office from a publishing agency approved as to its technical efficiency by the University of Chicago Press, and also as to its professional responsibility by the department concerned, that the dissertation has been received and accepted for publication.

The one hundred copies furnished to the General Library must be separate prints. They must contain no other material and must be put in covers (ninety-eight in paper covers and two in half-roan).

b) The candidate may deposit with the Business Office a legal financial guaranty sufficient to enable the University of Chicago Press to print the required one hundred copies, including the binding of two copies in half-roan. This guaranty shall mature at the expiration of two years from the date of the conferring of the degree.

c) The candidate may at his own cost secure publication of the dissertation in the form prescribed by the University, in which case the degree will be conferred only after the delivery of the required one hundred copies to the General Library.

Additional dissertation regulations:

d) Upon recommendation of a department and approval of the Dean of the Faculty immediately concerned, a form of the Doctor's dissertation briefer than that received in satisfaction of requirements for the degree may be accepted for publication. For instance, the alternative form of publication may be an account of the method pursued in the investigation, together with an abstract of the evidence used and a complete summary of the conclusions reached; or it may be a single chapter, provided the same represents a distinct unit of investigation.

e) In case the briefer form of the Doctor's dissertation is accepted for publication, five typewritten copies of the complete dissertation are required for deposit in the library in addition to the printed copies.

f) In case the course provided for in *d*) is adopted, arrangements for the same are made in the Dean's office before the expiration of the term fixed for publication.

g) Clauses *d*)–*f*) are held to modify other rules governing publication of dissertation in the one detail of providing for acceptance of a printed abbreviation in the place of the complete dissertation.

4. *Final examination.*—Plan I (see 2, *a*), p. 10): After admission to candidacy the student may present himself for examination as soon as he has fulfilled (1) the requirements of the department and (2) the dissertation requirements (see 3, p. 10). The examination will be conducted by a committee consisting of members of the department in which the degree is to be taken, and a representative of some other department, appointed by the Deans of the Graduate Schools. The candidate is required to prepare a typewritten or printed brief of his work, including an analysis of the dissertation, and to file six copies of the same with his Dean for distribution to the committee one week before the time set for the examination. In the case of the examination in the secondary department, the statement should include the work in this department, and the statement for the final examination should include the work of both departments.

Plan II (see 2, *a*), p. 10): After admission to candidacy the student may present himself for examination in his secondary subject or subjects as soon as he has fulfilled the requirements of the department or departments concerned. He may present himself for the examination in his principal subject, or in both principal and secondary subjects if the examination in the latter has not been taken in advance (1) as soon as he has fulfilled the requirements of the department or departments concerned, and (2) after he has made satisfactory arrangements as regards his dissertation. The examination will be conducted by a committee consisting of the members of the principal department concerned, an appointed representative of the secondary department, or a representative of each of them if there are two, of any other members of the secondary department who may choose to attend, and a member of some other department appointed by the Deans of the Graduate Schools. If the examination in the secondary subject or subjects is separated from the examination in the principal subject, the two may not be held in the same quarter, nor within two months of each other.

5. *Non-resident work.*—After being admitted, the student may be allowed to substitute non-resident work for resident work to a limited extent, under conditions to be arranged in consultation with the Dean and the heads of the departments concerned.

6. *Work done in other universities.*—Graduate work done in another university will be accepted as equivalent to resident work in the University of Chicago, provided the institution in which the work was done is of high standing, and adequate evidence is furnished that the work done there was satisfactorily performed. Graduate work done in other institutions cannot reduce the residence requirement at the University of Chicago to a period less than one year.[1]

[1] In order to avoid misunderstandings, candidates for higher degrees should consult their Deans concerning all technical requirements for such degrees before application is made for admission to candidacy. In all cases candidates should consult early with the heads of the departments of their major and minor subjects.

THE DEPARTMENT OF MATHEMATICS

OFFICERS OF INSTRUCTION

Eliakim Hastings Moore, Ph.D., LL.D., Sc.D., Math.D., Professor and Head of the Department of Mathematics.

Herbert Ellsworth Slaught, Ph.D., Sc.D., Professor of Mathematics.

George William Myers, Ph.D., Professor of the Teaching of Mathematics and Astronomy, the School of Education.

Leonard Eugene Dickson, Ph.D., Professor of Mathematics.

Gilbert Ames Bliss, Ph.D., Professor of Mathematics.

Ernest Julius Wilczynski, Ph.D., Professor of Mathematics.

Jacob William Albert Young, Ph.D., Associate Professor of the Pedagogy of Mathematics.

Arthur Constant Lunn, Ph.D., Associate Professor of Applied Mathematics.

Arthur Byron Coble, Ph.D., Professor and Acting Head, Department of Mathematics, University of Illinois (Summer, 1919).

Theophil Henry Hildebrandt, Ph.D., Assistant Professor of Mathematics, University of Michigan (Summer, 1919).

FELLOWS, 1919–20

Gladys Elizabeth Carson Gibbens, A.M. John Wayne Lasley Jr., A.M.
Edward Tankard Browne, A.M. Mayme Irwin Logsdon, S.B.
Frank Edwin Wood, A.M.

GENERAL AIMS

The courses in Mathematics are intended for those studying mathematics as a part of a liberal education, for those expecting to apply mathematics in other sciences or in technology, for prospective teachers of mathematics or other sciences in secondary schools, colleges, and universities, and for workers and investigators in the most advanced fields of mathematics.

ARRANGEMENT OF WORK

The student will be aided in planning his work in Mathematics by the classification of courses (in the list given later) as primarily of the Junior College, the Senior College, or the Graduate School, and by the specific prerequisites named for each course. But the proper arrangement of work in mathematics is of such extreme importance that students are urged to consult instructors of the Department in planning their work. For graduate students a formal system of registration is in use which requires personal conference with the instructor of each course to be taken, and quarterly consultation with the departmental adviser selected by the student.

MATHEMATICAL SEQUENCES FOR UNDERGRADUATES

All courses offered by the Department of Mathematics or given numbers in its printed Announcements (called "mathematical majors" in what follows) may be used in mathematical sequences, except those whose numbers begin with 0.

Courses admissible for sequences in the Departments of Physics and Astronomy may also be used in mathematical sequences to an amount not greater than one-third of the total number of majors.

Principal sequences.—A principal sequence may consist of any nine admissible majors provided at least three mathematical majors are included whose numbers are higher than 17.

Secondary sequences.—A secondary sequence may consist of any six admissible majors provided at least one mathematical major is included whose number is higher than 14.

The following are given as illustrations of typical sequences:

MATHEMATICS

Principal Sequences

a) Courses 1, 2, 3, 18, 19, 20, 47, 48, 49.
b) Courses 1, 2, 3, 18, 19, 23, 24, 31, 38.

Secondary Sequences

a) Courses 1, 2, 3, 18, 19, 20.
b) Courses 1, 2, 3, 15, 23 or 29, 31 or 34.

SEQUENCES FOR PROSPECTIVE TEACHERS

Principal Sequences

a) Courses 1, 2, 3, 18, 19, 23, 31, 37, 38.
b) Courses 1, 2, 6, 15, 26, 32, 34, 36 or 37, 39.

Secondary Sequences

Courses 1, 2, 3, 15, 23 or 31, 37 or 38.

MATHEMATICS AND ASTRONOMY

Principal Sequences

a) Courses 1, 2, 3, 18, 19, 20, Astronomy and Astrophysics 5, 6, 7.
b) Courses 1, 2, 3, 18, 19, Astronomy and Astrophysics 3A, 3B, 4.

Secondary Sequences

a) Courses 1, 2, 3, 15, Astronomy and Astrophysics 1, 7.
b) Courses 1, 2, 3, 15, Astronomy and Astrophysics 3A, 3B.

MATHEMATICS AND PHYSICS

Principal Sequences

a) Courses 1, 2, 3, 18, 19, 47, Physics 3, 4, 5, or 3S, 4S, 7.
b) Courses 1, 2, 3, 15, 23, 24, Physics 3, 4, 5, or 3S, 4S, 7.

Secondary Sequences

a) Courses 1, 2, 3, 15, Physics 3S, 4S.
b) Courses 1, 2, 3, 23, Physics 3S, 4S.

GROUPS OF COURSES

Certain Senior College and early graduate courses introductory to the higher mathematics may be grouped for reference as follows: (A) †Differential and integral calculus with applications (3Mjs.); (B) †Solid analytics; selected topics in geometry; theory of equations; determinants and elementary invariants; limits and series; (C) †Analytic mechanics (2Mjs.); vector analysis; celestial

mechanics (2Mjs.); (D) †Advanced calculus, †differential equations, †theory of definite integrals, elliptic integrals, Fourier series and Bessel functions, elements of the theory of functions; (E) Synthetic projective geometry; analytic projective geometry; differential metric geometry; differential projective geometry; (F) Theory of numbers; theory of invariants; selected chapters of algebra; theory of substitutions with applications to algebraic equations.

NOTE.—The courses marked † are given annually; the other courses usually once in two years.

These courses and the special courses in the Higher Mathematics are intended to give the student a comprehensive view of modern mathematics, to develop him to scientific maturity, and to enable him to follow, without further guidance, the scientific movement of the day in mathematics, and, if possible, to take an active part in it by creative research.

The special and research courses vary from year to year. They may be classified, in general, as relating to (*a*) Algebra and Arithmetic; (*b*) Analysis; (*c*) Geometry; (*d*) Mechanics and Applied Mathematics; and (*e*) the Foundations and Interrelations of the Mathematical Disciplines as purely abstract deductive systems. Courses of type (*d*) are also offered by the Departments of Astronomy and Physics.

PREPARATION FOR TEACHING

Courses in the history and the teaching of Elementary Mathematics—Arithmetic, Algebra, Geometry, Trigonometry, Analytic Geometry, Calculus, Mechanics—are offered by this Department and the School of Education. These courses embody the conviction that elementary students need to have their mathematics made not easier but more perfectly intelligible and attractive. To this end it is believed that teachers should more generally appreciate and utilize in instruction the unity of mathematics, as made up of various closely interrelated parts, and the character of mathematics, as an ideal science developed by abstraction from various more concrete domains.

A) *Secondary-school positions.*—Students who expect to teach mathematics as a major subject in secondary schools should complete at least the following courses in their undergraduate career: (1) Courses in pure mathematics: Trigonometry, College Algebra, Plane Analytic Geometry, Differential and Integral Calculus and Applications of Calculus, Theory of Equations, and the Synoptic course; (2) Courses in applied mathematics: Descriptive Astronomy, Mechanics, and General Physics; (3) The two courses, Principles of Education and Methods of Education, which may be taken either in the Junior College or in the Senior College; (4) Practice Teaching in Mathematics in the University High School, for which the foregoing courses in education are prerequisite; (5) A course in the Teaching of Secondary Mathematics and a course in the History of Secondary Mathematics.

B) *Minor collegiate positions.*—Those who look forward to teaching mathematics in normal schools and small colleges should as undergraduates complete at least the following courses: (1) The general courses in education and those in the history and teaching of mathematics mentioned in (3) and (5) above; (2) The content courses specified in (1) and (2) above, together with Advanced Calculus (3 majors).

Candidates for these positions should take at least one year of graduate work leading to the Master's degree in Mathematics and during this year should visit some of the college courses in Mathematics with the purpose of observing methods of teaching.

C) *University positions.*—Candidates for university positions should qualify for the Doctor's degree. Courses in the history of mathematics and in the principles and practice of education are strongly recommended.

HIGHER DEGREES

Master's degree.—Candidates for the Master's degree in Mathematics are expected, on the basis of a principal sequence of nine majors of undergraduate mathematics, to offer for examination eight approved courses of groups (A)–(E), including the elements of the theory of functions, and to present a satisfactory dissertation on an assigned topic closely related to the subject of one of the courses.

Degree of Doctor of Philosophy.—Candidates for the Doctor's degree with Mathematics as secondary subject are expected to offer for examination nine approved courses in advance of course 3.

Candidates for the Doctor's degree with Mathematics as principal subject are expected (1) to offer for examination the subjects covered by fifteen majors of initial courses of groups (B)–(F), including two of each of the types (*a*)–(*e*), and by a considerable body of special courses, in each case presumably most closely related to the subject of the doctoral dissertation, and (2) to present a dissertation, in finished form, embodying valuable results of mathematical inquiry. The subject of the dissertation may be a topic of pure or applied mathematics or of the history, philosophy, or pedagogy of mathematics.

MISCELLANEOUS INFORMATION

Clubs.—The Departmental Club meets regularly for the review of memoirs and books, and for the presentation of results of research. The club is conducted by the members of the Faculties of Mathematics and Mathematical Astronomy. Graduate students of the Departments are expected to attend and otherwise to participate in the meetings of the club.

The Junior Mathematical Club, with fortnightly meetings, is conducted by the graduate students of the Departments of Mathematics and of Astronomy and Astrophysics.

Library.—The library contains the more important works on mathematics (about 7,200 volumes) and has current issues and complete files of the leading periodicals.

Models.—The collection of models includes a set of Brill's models: plaster and thread models of quadric surfaces, plaster models of cubic and Kummer's quartic surfaces, models of cyclides and surfaces of constant positive and negative curvature, and thread models of three-dimensional projections of four-dimensional regular bodies.

Summer Quarter.—The courses of the Summer Quarter are planned with special reference to the needs of those who are able to spend only the summer in residence. The courses are arranged so as to enable the student to continue his

work progressively in successive summers, and so that the courses of four consecutive summers give a wide view of modern mathematics. The student who is obliged to leave before the close of the Summer Quarter may usually arrange to complete his work by correspondence.

Scholarship examinations.—The competitive examinations for the Senior College Scholarship and for the Graduate Scholarship in Mathematics are held each Spring Quarter at times and places announced in the *Weekly Calendar*. Prospective candidates should confer with the Departmental Examiner in Mathematics. Files of papers set at previous Scholarship examinations are accessible in the Departmental Library. Candidates for the Senior College Scholarship will be examined on courses 1, 2, and 3; those for the Graduate Scholarship on courses 18, 19, 20, 23, 24, 31, 47, 48, and 49.

COURSES OF INSTRUCTION

I. JUNIOR COLLEGE COURSES

00. Advanced Algebra.[1]—A collegiate treatment of quadratic equations and other topics of the third semester of algebra of the secondary school. For students who offer only one unit of mathematics for entrance. Mj. Autumn, Mr. ———.

1. Plane Trigonometry.—Mj. Summer, Associate Professor Young; Autumn, 2 sections, Professor Slaught and Mr. ———; Winter, 2 sections, Mr. ——— and Mr. ———; Spring, 2 sections, Professor Slaught and Mr. ———.

2. College Algebra.—Mj. Summer, Professor Wilczynski; Mj. Autumn, Mr. ———; Winter, Professor Wilczynski; Spring, Professor Slaught.

3. Analytic Geometry.—Elements of plane analytics, including the geometry of the conic sections, with an introduction to solid analytics. Prerequisite: course 1. Mj. Summer, Professor Coble; Autumn, Professor Moore; Winter, Associate Professor Young; Spring, Professor Dickson.

7, 8, 9. Applied Mathematics I, II, III.—An intensive training course in mathematical methods for students who expect to undertake scientific work; in close connection with corresponding courses offered by the Departments of Physics and Chemistry. Numerical and algebraic computations, mensuration and trigonometry, graphical methods and the main notions of analytic geometry, together with the differential and integral calculus of a few elementary functions. Topics will be chosen with primary reference to their bearing on physics, chemistry, and engineering, and problems from those sources will constitute the bulk of the illustrative material used. Prerequisite: Satisfactory preparation in elementary algebra and geometry and previous or simultaneous work in physics. Three consecutive majors. Autumn, Winter, and Spring, Associate Professor Lunn.

15. Introductory Calculus.[2]—The elementary fundamental principles, methods, and formulas of differential and integral calculus will be carefully studied in connection with simple problems of geometry and the physical sciences. This course is intended primarily for those who do not wish to take the longer course in Calculus (courses 18, 19, and 20). Prerequisite: course 1. Mj. Spring, Associate Professor Young.

[1] Limited-credit course: After a student has credit for 18 majors but less than 27, these courses will be credited at one-half major each; after he has credit for 27 majors they will not be credited at all.

[2] See footnote for course 18.

II. SENIOR COLLEGE COURSES

18,[1] 19, 20. Calculus I, II, III.—A development of the three fundamental notions of the Calculus: the derivative, the anti-derivative, the definite integral, with especial emphasis on their geometric interpretations and their relations to problems in geometry, mechanics, and physics. Prerequisite: courses 1, 2, and 3. Three consecutive majors. Autumn, Winter, and Spring, 2 sections, PROFESSOR BLISS.

18,[1] 19. Calculus I, II.—Prerequisite: courses 1, 2, and 3. Two consecutive majors. Winter and Spring, 2:00, ASSOCIATE PROFESSOR YOUNG.

18. Calculus I: Differential Calculus.—A graphic study of rational algebraic functions and of certain simple irrational transcendental functions, yielding material for a geometric introduction to the fundamental notions and processes of the Calculus. Prerequisite: courses 1, 2, and 3. Mj. Summer, PROFESSOR BLISS.

19. Calculus II: Integral Calculus.—A course aimed at a comprehension of the nature of integration and of its applications to geometry and physics; solution of numerous problems; use of table of integrals. Prerequisite: course 18. Mj. Summer, PROFESSOR SLAUGHT.

21. Advanced Calculus.—Selected topics in the Differential and Integral Calculus requiring more extensive and theoretic treatment than is given in courses 18 and 19: for example, development of the formulas for successive differentiation and the differentiation of implicit functions, Taylor's formula with applications, transformation of variables in different equations and multiple integrals, line integrals and partial integration of multiple integrals. Prerequisite: courses 18 and 19. Mj. Autumn. [Not given in 1919.]

22. Elementary Theory of Equations.—The course covers those sections of Dickson's *Elementary Theory of Equations* which are not marked by a dagger. Prerequisite: Differential Calculus. Mj. Autumn, PROFESSOR DICKSON.

23. Solution of Numerical Equations.—Isolation of the real roots by graphic methods and by use of Sturm's functions; Newton's and Horner's methods of solution; algebraic solution of cubic and quartic equations. Text: Dickson's *Elementary Theory of Equations*. Prerequisite: Differential Calculus. M. Summer, First Term, PROFESSOR DICKSON. [Not given in 1919.]

24. Determinants and Symmetric Functions.—With applications to systems of linear equations and the theory of elimination. Text and prerequisite as in course 23. Students may enter without course 23 if thoroughly familiar with college algebra. M. Summer, Second Term, PROFESSOR DICKSON. [Not given in 1919.]

28. Selected Topics in Mathematics.—Based on certain parts of the "Monographs on Topics of Modern Mathematics Relevant to the Elementary Field," edited by J. W. A. Young. Mj. [Not given in 1919–20.]

29. Synthetic Projective Geometry.—A development of projective geometry from the purely synthetic standpoint. Fundamental forms of the first and second orders; conic sections and surfaces of the second order; involution with applications; quadratic transformations, plane systems, point systems and space systems projectively related, with some study of space curves and of line geometry. [Not given in 1919–20.]

29, 30. Projective Geometry I, II.—The fundamental notions of projective geometry treated both analytically and synthetically. The method of abbreviated notation and homogeneous co-ordinates. Theory of determinants and their application to the geometry of two and three dimensions. Projective

[1] If a student has credit for course 15, credit will be given for course 18 only in case the latter is completed with the standing of B− or better.

and dualistic transformations and the simpler Cremona transformations. Notions of group and invariant. Prerequisite: courses 1, 2, 3, 18, 19. Two consecutive majors. Winter and Spring, PROFESSOR WILCZYNSKI.

31. Solid Analytics.—This course may be taken simultaneously with course 18; it is an advisable antecedent of course 19. Prerequisite: courses 3 and 18. Mj. Summer, ASSOCIATE PROFESSOR YOUNG; Mj. Winter, PROFESSOR DICKSON.

34. Limits and Series.—Definitions and fundamental properties of various types of limits. Prerequisite: Differential and Integral Calculus. Mj. Summer, ASSISTANT PROFESSOR HILDEBRANDT; Mj. Spring, PROFESSOR MOORE.

The Teaching of Elementary-School Mathematics (School of Education: Mathematics 1).—Mj. Winter, PROFESSOR MYERS.

The Teaching of Secondary Mathematics (School of Education: Mathematics 2).—Mj. Spring, PROFESSOR MYERS.

History of Mathematics (School of Education: Mathematics 5).—Mj. Winter, PROFESSOR MYERS.

37. Critical Review of Secondary Mathematics.—A brief survey of the subject-matter of Secondary Mathematics from the modern point of view, aiming both to organize the theory of the whole scientifically and to gather the products of this work for use in teaching. Primarily for teachers, actual and prospective, but open also to others. Mj. Summer, ASSOCIATE PROFESSOR YOUNG. [Not given in 1919.]

38. Synoptic Course in Advanced Mathematics.—A general historical and logical survey of a considerable portion of pure and applied mathematics. Prerequisite: courses 1, 2, and 3. Mj. PROFESSOR WILCZYNSKI. [Not given in 1919–20.]

Analytic Mechanics I, II (Astronomy 5, 6).—An introductory course. Prerequisite: Mathematics 18, 19. 2Mjs. Autumn and Winter, ASSOCIATE PROFESSOR LAVES.

40. Topics of Geometry.—The topics will be selected from the following: foundations of geometry, nature and value of geometric reasoning, methods of solution of geometric problems, limits in geometry; anharmonic ratio, complete quadrilateral, polars, duality, modern geometry of the triangle, geometric conics, and others. There will be much work in actual solution of problems. Prerequisite: entrance plane geometry. [Not given in 1919.]

47. Differential Equations.—A study of the more common types of ordinary differential equations, especially those of the first and second orders, with emphasis on geometrical interpretations and applications to geometry, elementary mechanics, and physics. Prerequisite: courses 18, 19, and preferably 20. Mj. Autumn, PROFESSOR SLAUGHT.

48. Elliptic Integrals.—A systematic development of the theory of indefinite integration, leading to elliptic integrals and the elements of elliptic functions, with attention to problems and applications. This course includes also an introduction to Fourier series. Prerequisite: courses 18, 19, 20, and preferably 46 or 47. Mj. Summer, PROFESSOR SLAUGHT.

49. Theory of Definite Integrals.—A course treating of the properties and methods of computing definite integrals, including a study of methods of approximation, improper definite integrals, Eulerian integrals, multiple integrals, with many problems and applications. Prerequisite: course 47. Winter, PROFESSOR MOORE.

50. Fourier Series and Bessel Functions.— (*a*) A study of the properties of Bessel functions in connection with the solution of a variety of physical problems where they occur directly. (*b*) Trigonometric and Bessel series as solutions of partial differential equations. Byerly's "Fourier Series." Mj. Spring, ASSOCIATE PROFESSOR LUNN. [Not given in 1920.]

III. GRADUATE COURSES

NOTE.—Students should register for graduate courses only after consultation with instructors.

65A, B, C, D. Reading and Research in Pure Mathematics.—When in the judgment of the Department it is advisable that students undertake definite mathematical reading and research not closely connected with any current lecture course or seminar, this work will be directed by PROFESSOR MOORE, PROFESSOR DICKSON, PROFESSOR BLISS, OR PROFESSOR WILCZYNSKI. Mj. or DMj. each Quarter.

66A, B, C. Reading and Research in Applied Mathematics.—Advisable reading and research will be directed by PROFESSORS MOORE AND MYERS, OR ASSOCIATE PROFESSOR LUNN. Mj. or DMj. each Quarter.

71. Theory of Numbers.—Introductory course. Theory of congruences, the quadratic reciprocity theorem, and the theory of quadratic forms. Mj. Autumn, 1921, PROFESSOR DICKSON.

74. Theory of Algebraic Numbers.—Prerequisite: course 71. Mj. Winter, 1922, PROFESSOR DICKSON.

75. History of the Theory of Numbers.—Development from the historical standpoint of fundamental topics in the theory of numbers. The course is an introductory one, open to Senior College students after consultation with the instructor. Mj. Spring, 1921, PROFESSOR DICKSON.

81. Substitution Groups and Algebraic Equations.—An introduction to the theory of groups of substitutions and the Galois theory of algebraic equations, with applications to geometry. Text: Miller, Blichfeldt, and Dickson's *Theory and Applications of Finite Groups*. Mj. Spring, 9:15, PROFESSOR DICKSON.

82. Finite Groups.—Selected topics on substitution groups, abstract groups, finite linear and collineation groups. Text as in course 81. Mj. Spring, PROFESSOR DICKSON.

84. Continuous Groups.—An illumination of the fundamental concepts and theorems of the Lie theory in connection with various classes of problems of geometry and differential equations. Mj. Autumn, PROFESSOR DICKSON; Mj. Summer, 1921, PROFESSOR BLISS.

91. Introduction to Higher Algebra.—Properties of matrices, invariant factors, and elementary divisors; algebraic theory of a single quadratic or bilinear form; theory of pairs of quadratic or bilinear forms. Geometrical applications. Based largely upon Bôcher's *Introduction to Higher Algebra*. Mj. Autumn, 1920, PROFESSOR DICKSON.

93. Theory of Algebraic Invariants.—An introduction to the non-symbolic theory of invariants of binary forms, with applications to geometry, followed by an explanation of the symbolic notation, with practice in its use. Based on Dickson's *Algebraic Invariants*. Mj. Winter, PROFESSOR DICKSON.

98. Linear Algebras.—An introduction to the theory of hypercomplex numbers, with attention to quaternions, the relations of the theory to matrices, bilinear forms, and groups. Text: Dickson's *Linear Algebras*, 1914, Cambridge Tracts on Mathematics and Mathematical Physics. Mj. Spring, 1922, PROFESSOR DICKSON.

101A. Theory of Functions of a Real Variable.—A discussion of the classical types of limits for series, sequences, and definite integrals. The principal results in the elementary theory of point sets. Theorems concerning the continuity, derivation, and integration of functions and series of functions. Mj. Summer, ASSISTANT PROFESSOR HILDEBRANDT.

101B. Theory of Functions of a Real Variable.—A study of the existence theorems for implicit functions, ordinary and partial differential equations, and their applications in Analysis, especially to the Calculus of Variations. Mj. Autumn, PROFESSOR BLISS.

102. Ordinary Linear Differential Equations of the Second Order.—Existence theorems (real case), the analogy between linear algebraic and linear differential equations, theorems of comparison and oscillation, characteristic numbers and functions, expansion of arbitrary functions, Green's functions. Prerequisite: an elementary knowledge of the theory of functions of a real variable. Mj. [Not given in 1919–20.]

104. Calculus of Variations.—Examples illustrating the various types of problems. The differential equations of a curve which minimizes a definite integral in a space of two or more dimensions. Other properties of a minimizing curve as deduced by Legendre, Weierstrass, and Jacobi for the case of the plane. Conditions which insure the existence of a minimum. Isoperimetric problems and the more general problems of Lagrange and Mayer. An introduction to the theory of double integrals. Prerequisite: course 101. Winter, PROFESSOR BLISS.

105. Functions of Lines.—Special cases which occur in the calculus of variations and the theory of integral equations. The derivations of Volterra and the differentials of Fréchet, with applications to maxima and minima and implicit functions. The theory of composition of functions and the solution of general types of integral and integro-differential equations. Prerequisite: course 104. Mj. Spring, PROFESSOR BLISS.

106. Partial Differential Equations.—The geometrical theory of equations of the first order. Linear equations. Systems of equations of the first order. Introduction to equations of the second order. Applications to geometry and physics. Mj. Spring, 1922, PROFESSOR BLISS.

108. Differential Equations from the Standpoint of Lie.—The relations between continuous groups and differential equations. The Picard-Vessiot theory of linear differential equations. Mj. Summer; Mj. Winter, 1922, PROFESSOR BLISS.

111. Classes of Functions and Functional Operations in General Analysis.—Based on Moore's *Introduction to a Form of General Analysis*. The general analysis in question is the theory of systems of classes of functions, functional operations, etc., involving at least one general variable on a general range. A general variable is a variable entering the theory without direct characterization as to quality or range of variation. A real- and single-valued function ξ of a general variable p has as especially important particular instances: (I) a real number ξ, the variable p having only one value; (II) an n-partite real number $\xi=(\xi_1, \ldots, \xi_n)$, or point ξ in real space of n dimensions, the variable p having the values $p=1, 2, \ldots, n$; (III) an infinite sequence $\xi=(\xi_1, \xi_2, \ldots, \xi_n, \ldots)$ of real numbers, the variable p having the values $p=1, 2, \ldots, n, \ldots$; (IV) a function ξ or $\xi(p)$ of the variable p on the linear interval $0 \leqq p \leqq 1$ of the real number system. The first part of this introductory course considers certain fundamental closure and dominance properties of classes of functions of a general variable, properties possessed in particular by the class: (I) of all real numbers; (II) of all n-partite real numbers; (III_0) of all numerical sequences converging to zero; (III_1) of all absolutely convergent series of real numbers; (IV) of all continuous functions of p on the interval $0 \leqq p \leqq 1$. The course presupposes a knowledge of the elements of the theory of functions of real variables. For second-year graduate students. Mj. Autumn, PROFESSOR MOORE.

112. Matrices in General Analysis.—Hermitian matrices of positive type and associated integration processes. A generalization of the work of Hilbert and Hellinger with reference to an arbitrary hermitian matrix of positive type. For second-year graduate students. Mj. Autumn, 1920, PROFESSOR MOORE.

113, 114. Theory of Functions of Infinitely Many Variables in General Analysis.—Prerequisite: course 112. Two consecutive majors. Winter, Spring, 1921, PROFESSOR MOORE.

115, 116. Integral Equations in General Analysis.—Application of the methods of course 111 to a study of the general Fredholm and Hilbert-Schmidt theories of integral equations. Two consecutive majors. Winter, Spring, PROFESSOR MOORE.

121. Theory of Functions of the Complex Variable.—Introduction to the algebra and calculus of complex numbers and their geometric representation; conform representation. The theory of power series and the properties of analytic functions. Introduction to the theory of Riemann surfaces. Prerequisite: courses 47 and 49. Autumn, 1920, PROFESSOR BLISS.

122. Algebraic Functions.—The analytic character of an algebraic function and its geometrical representation by means of a Riemann surface. Abelian integrals on the Riemann surface, with especial attention to the hyperelliptic case. Abel's theorem. Introduction to the theory of the inversion of Abelian integrals. Prerequisite: course 121. Mj. Winter, 1921, PROFESSOR BLISS.

123. Elliptic Functions.—Elliptic integrals and the Weierstrassian theory of elliptic functions. Applications of elliptic functions. Mj. Spring, 1921, PROFESSOR BLISS.

125. Elliptic Modular Functions.—After a preliminary discussion of elliptic integrals in general and the definition of the initial pair of periods ω_1, ω_2, of the integral J of Weierstrass the J-plane is mapped upon the ω-plane ($\omega = \omega_1/\omega_2$) by means of the initial branch of ω (J) and the remaining branches are derived. The group properties of the modular functions are then discussed and explicit expressions for some such functions are derived from the elliptic norm curve. Prerequisite: a first course in the theory of functions of a complex variable. Mj. Summer, PROFESSOR COBLE.

130. Foundations of Geometry.—A critical study of geometry by the method of postulates based on the work of Hilbert and his successors. Mj. Spring, PROFESSOR MOORE. [Not given in 1920.]

141. Analytic Projective Geometry.—Analytic treatment of the projective properties of the straight line and of the conic sections. Prerequisite: familiarity with the fundamental concepts of projective geometry and a good knowledge of the calculus. Mj. [Not given in 1919–20.]

142. Higher Plane Curves.—General properties of algebraic curves. Special study of the curves of the third and fourth order. Mj. PROFESSOR BLISS. [Not given in 1919–20.]

144. Line Geometry.—The line co-ordinates of Plücker and Klein. Complexes, congruences, and ruled surfaces. Prerequisite: course 31. Mj. Spring, 1921, PROFESSOR WILCZYNSKI.

145. Higher Geometry.—A general survey of the principal methods and results of recent geometric research. The various systems of co-ordinates and space elements, the rôle of the group concept, and the cultivation of space intuition by the use of models. Prerequisite: Differential Equations, Projective Geometry, and Solid Analytic Geometry. Mj. Spring, PROFESSOR WILCZYNSKI.

151, 152. Metric Differential Geometry.—The application of the Calculus to the metric theory of twisted curves and surfaces in space. Prerequisite: course 31. Two consecutive majors, Autumn, 1920, Winter, 1921, PROFESSOR WILCZYNSKI.

151. Metric Differential Geometry.—Mj. Summer, PROFESSOR WILCZYNSKI.

154, 155. Projective Differential Geometry I, II.—This course gives a brief account of Lie's theory, with applications to the theory of invariants of systems of linear differential equations. The projective differential properties of plane and space curves, of surfaces and congruences, then present themselves as a result of interpreting this invariant theory geometrically. Text: Wilczynski's *Projective Differential Geometry of Curves and Ruled Surfaces.* (B. G. Teubner, Leipzig, 1906.) Prerequisite: an elementary knowledge of differential equations and projective geometry. Two consecutive majors, Autumn, Winter, 1922, PROFESSOR WILCZYNSKI.

156. Theory of Plane Curves.—Projective and metric differential and integral properties. Texts: Salmon's *Higher Plane Curves* and Wilczynski's *Projective Differential Geometry of Curves and Ruled Surfaces.* Prerequisite: an

elementary knowledge of differential equations and projective geometry. Mj. PROFESSOR WILCZYNSKI. [Not given in 1919–20.]

157. Theory of Ruled Surfaces and Space Curves.—Primarily from the point of view of projective differential geometry. Text: Wilczynski's *Projective Differential Geometry of Curves and Ruled Surfaces.* Prerequisite: course 156. Mj. PROFESSOR WILCZYNSKI. [Not given in 1919–20.]

158. Theory of Surfaces and Congruences, with special emphasis upon the projective differential properties.—Prerequisites: Mathematics 157. Mj. PROFESSOR WILCZYNSKI. [Not given in 1919–20.]

160. Vector Analysis.—The elements of vector algebra, vector differentiation and integration, and the linear vector function; illustrated by typical applications to geometry, mechanics, and physics. Prerequisite: courses 31 and 49. Mj. Autumn, ASSOCIATE PROFESSOR LUNN.

162. Applications of Vector Analysis in the Theory of Electromagnetism.—Formulation of the Maxwell-Lorentz theory in terms of vector analysis. Hydrokinetic analogies and the geometry of scalar and vector fields. Fundamental problems in integration. Introductory study of vectors in four dimensions. Prerequisite: course 160. Mj. Winter, ASSOCIATE PROFESSOR LUNN.

163. Theory of Attraction and the Potential.—The potential function of gravitation and electrostatics; Laplace's equation, Green's function, and harmonic analysis; extensions to cases of heterogeneous media, with sketch of the abstract theory as related to linear differential equations of the second order. Emphasis will be laid on the solutions of illustrative problems. Pierce's *Newtonian Potential Function.* Prerequisite: courses 49 and 160. Mj. Autumn, 1920, ASSOCIATE PROFESSOR LUNN.

164. Dynamics of Oscillatory Systems: Theory of Sound.—Mj. Winter, 1922, ASSOCIATE PROFESSOR LUNN.

166. Hydrodynamics.—Kinematics of continuous media and dynamical theory of typical forms of motion in perfect and viscous fluids, with special emphasis on analytic methods of general use in mathematical physics. Mj. Autumn, 1921, ASSOCIATE PROFESSOR LUNN.

167. Theory of Elasticity.—The geometry of strain in a continuous medium, dynamic relations of stress and strain; detailed study of selected problems in the equilibrium and motion of elastic solids. Prerequisite: Advanced Calculus and Analytic Mechanics. Mj. ASSOCIATE PROFESSOR LUNN. [Not given in 1919–20.]

170. Probability and Statistics.—The theory of average and probability for finite and infinite sets of elements; the statistical treatment of observations and the method of least squares; introduction to statistical mechanics, with examples from the theories of molecules and electrons. Prerequisite: Differential Equations. Mj. ASSOCIATE PROFESSOR LUNN. [Not given in 1919–20.]

171. Statistical Mechanics.—This course deals with the mathematical methods used in the treatment of those physical theories where the magnitudes directly accessible to measurement are conceived as averages of multitudes of elements and physical laws are interpreted as examples of statistical regularity. A brief preparatory treatment of the notions of statistics and of the main features of the theory of probability, with some examples in geometry and kinematics, will lead to the main work of the course, in the kinetic theory of gases, the electron theory of metals, and some aspects of the theory of radiation. Prerequisite: thorough knowledge of the Calculus. Mj. Winter, ASSOCIATE PROFESSOR LUNN. [Not given in 1920.]

172. Partial Differential Equations of Mathematical Physics; the Conduction of Heat.—A study of certain typical linear partial differential equations occurring in the analytic representation of physical theories and of the functional expansions of solutions satisfying given boundary conditions, with special reference to the concrete phenomena and physical analogies from which the

abstract theory has been generalized. Prerequisite: courses 49 and 160. Mj. Winter, 1921, Associate Professor Lunn.

178. The Theory of Relativity.—After a brief historical introduction on the notion of relativity of time and space in its classic or Newtonian form, the course will be devoted to a study of the recent theory initiated by Einstein and Minkowski as a geometry of space and time adapted to the representation of physical laws. Special attention will be given to the discrimination between the logical elements of the theory and the special concrete interpretations that may be used in the formulation of experimental results. Mj. Spring; Mj. Summer, 1921, Associate Professor Lunn.

Attention is called to the following courses in the Department of Physics:

27. Units and Dimensions.—The theory of units and dimensions as applied to the measurement of concrete magnitudes and the mathematical transcription of physical experiments. Physical similitude and the interpretation of models. Numerical computations and the reduction of observations. Prerequisite: General Physics and some knowledge of Calculus. Mj. Summer, 7:10, Associate Professor Lunn.

64. Electromagnetic Theory.—(*a*) The main experimental facts of electromagnetism and their generalization so far as covered by the Maxwell theory in its abstract form; special problems concerning steady fields, induction, and electromagnetic waves. M. First Term. (*b*) The electronic interpretation and extension of the Maxwell theory; electromagnetic mass; theory of radiation and conduction; problems relating to moving bodies. M. Second Term, Summer, 8:10, Associate Professor Lunn.

For descriptions of the following courses see the announcement of the Department of Physics:

173. Physics 63. Geometric Optics.—Mj. Spring, Associate Professor Lunn.

174. Physics 11. Heat and Molecular Physics.—Mj. Autumn, Associate Professor Lunn.

175. Physics 51. Thermodynamics.—Mj. Winter, Associate Professor Lunn.

176. Physics 67. Radiation and Quantum Theory.—Mj. Spring, Associate Professor Lunn.

177. Electron Theory. Physics 52.—Mj. Autumn, Associate Professor Lunn.

CONSPECTUS OF COURSES OFFERED BY THE DEPARTMENT OF MATHEMATICS, 1919–20

Summer, 1919	Autumn, 1919	Winter, 1920	Spring, 1920
1. Plane Trigonometry (Young)	00. Advanced Algebra (———)	1. Plane Trigonometry (*a*) (———) (*b*) (———)	1. Plane Trigonometry (*a*) (Slaught) (*b*) (———)
2. College Algebra (Wilczynski)	1. Plane Trigonometry (*a*) (Slaught) (*b*) (———)	2. College Algebra (Wilczynski)	2. College Algebra (Slaught)
3. Analytic Geometry (Coble)	2. College Algebra (———)	3. Analytic Geometry (Young)	3. Analytic Geometry (Dickson)
18. Calculus I (Bliss)	3. Analytic Geometry (Moore)	8. Applied Mathematics II (Lunn)	9. Applied Mathematics III (Lunn)
19. Calculus II (Slaught)	7. Applied Mathematics I (Lunn)	18. Calculus I (Young)	15. Introductory Calculus (Young)
31. Solid Analytics (Young)	18. Calculus I (Bliss)	19. Calculus II (Bliss)	19. Calculus II (Young)
34. Limits and Series (Hildebrandt)	22. Elementary Theory of Equations (Dickson)	29. Projective Geometry I (Wilczynski)	20. Calculus III (Bliss)
48. Elliptic Integrals (Slaught)	47. Differential Equations (Slaught)	31. Solid Analytics (Dickson)	30. Projective Geometry II (Wilczynski)
101. Theory of Functions of a Real Variable (Hildebrandt)	84. Continuous Groups (Dickson)	49. Theory of Definite Integrals (Moore)	34. Limits and Series (Moore)
108. Differential Equations (Lie Theory) (Bliss)	101. Theory of Functions of a Real Variable (Bliss)	93. Theory of Algebraic Invariants (Dickson)	82. Finite Groups (Dickson)
125. Elliptic Modular Functions (Coble)	111. Classes of Functions and Functional Operations in General Analysis (Moore)	104. Calculus of Variations (Bliss)	105. Functions of Lines (Bliss)
151. Metric Differential Geometry (Wilczynski)	160. Vector Analysis (Lunn)	115. Integral Equations in General Analysis (Moore)	116. Integral Equations in General Analysis (Moore)
		162. Applications of Vector Analysis in the Theory of Electromagnetism (Lunn)	145. Higher Geometry (Wilczynski)
			178. The Theory of Relativity (Lunn)

THE DEPARTMENT OF ASTRONOMY AND ASTROPHYSICS

OFFICERS OF INSTRUCTION

EDWIN BRANT FROST, A.M., Sc.D., Professor of Astrophysics; Director of the Yerkes Observatory.

SHERBURNE WESLEY BURNHAM, A.M., Sc.D., Emeritus Professor of Practical Astronomy at the Yerkes Observatory.

EDWARD EMERSON BARNARD, A.M., Sc.D., LL.D., Professor of Practical Astronomy at the Yerkes Observatory.

FOREST RAY MOULTON, PH.D., Professor of Astronomy.

KURT LAVES, PH.D., Associate Professor of Astronomy.

JOHN ADELBERT PARKHURST, S.M., Assistant Professor of Practical Astronomy at the Yerkes Observatory.

STORRS BARROWS BARRETT, A.B., Assistant Professor of Astrophysics; Secretary and Librarian of the Yerkes Observatory.

WILLIAM DUNCAN MACMILLAN, PH.D., Assistant Professor of Astronomy.

GEORGES VAN BIESBROECK, DR.ENG., Assistant Professor of Practical Astronomy at the Yerkes Observatory.

OLIVER JUSTIN LEE, S.M., PH.D., Instructor in Practical Astronomy at the Yerkes Observatory.

EDISON PETTIT, E.B., Assistant in Practical Astronomy.

HANNAH STEELE PETTIT, A.M., Assistant for Stellar Parallax.

FELLOWS, 1919–20

ALICE HALL FARNSWORTH, S.M. FREDERICK CHARLES LEONARD, S.B.

INTRODUCTORY

The work of the Department of Astronomy and Astrophysics is divided into two parts:

(1) Work at the University, comprising: (*a*) elementary instruction in general Astronomy, both theoretical and practical; (*b*) preliminary training in the principles and methods of work underlying the science of Astrophysics (given in part in the Department of Physics); (*c*) graduate and research work in Celestial Mechanics.

(2) Graduate and research work in Practical Astronomy and Astrophysics in the Yerkes Observatory at Williams Bay, Wisconsin.

At the University, in the work given by Professor Moulton, Associate Professor Laves, and Assistant Professor MacMillan, emphasis will be laid on the development of the mathematical principles and methods which form the basis of the physical sciences. In addition to the courses in Descriptive Astronomy, Introduction to Celestial Mechanics, and Analytic Mechanics, courses in Periodic Orbits and in the various other branches of Celestial Mechanics will be given within periods not exceeding three years. The most fundamental subjects will be arranged so as to recur at regular intervals, while other more special topics will vary from time to time. The general object of the instruction will be to give experience and preliminary training in the work of observation and reduction; to furnish the student an adequate mathematical basis for successful work in

Celestial Mechanics, and to direct research work in Celestial Mechanics. The Departmental Club meets fortnightly for the review of memoirs and books and for the presentation of results of research. The club is conducted by the members of the Faculties of Mathematics and Mathematical Astronomy. Graduate students of Mathematical Astronomy are expected to attend regularly and, so far as possible, to participate actively in the meetings of the club.

At the Yerkes Observatory the advanced student is made familiar with modern methods of research in various branches of Practical Astronomy and Astrophysics. The rapid development of the latter science within the last two decades has been fully recognized in the equipment of the Observatory; the special laboratory facilities make some investigations possible which cannot be carried on where the equipment is less complete. In general, the work in progress during the year 1918–19 will include: researches in solar physics with the spectroscope, spectroheliograph, and photoheliograph; micrometric observations of double stars, planets, satellites, nebulae, and comets; studies of photographic stellar spectra and determinations of motions in the line of sight; photography of stars, comets, nebulae, etc.; photographic investigations of stellar parallax; research in visual and photographic photometry; special astrophysical researches. The opportunity of taking part in these investigations is deemed of more advantage to the qualified student than set courses of instruction; but regular programs of work, with courses of collateral reading, will be laid out as conditions require. During the Summer Quarter illustrated lectures particularly intended for graduate students are given on one evening of each week by members of the staff. The Astronomical Club also meets regularly—weekly during the Summer Quarter—for the discussion of assigned topics in Astronomy and Astrophysics.

FACILITIES

For instruction in Practical Astronomy a students' observatory is maintained. It is equipped with a modern Warner & Swasey equatorial telescope of 6½ inches aperture, which is provided with a filar micrometer, a 5-inch refractor, a 3-inch Bamberg transit instrument, a Bamberg universal instrument, a Riefler sidereal clock, a chronometer, and various smaller accessories. The laboratory courses offered by the Department of Physics afford excellent preliminary training for the work in Astrophysics.

For a description of the Yerkes Observatory, see the *Annual Register* of the University of Chicago, Part V, of this volume. An illustrated pamphlet of 24 pages, describing the observatory in detail, may be obtained on application.

DEGREES

The Master's degree.—Students working for a Master's degree in Astronomy are advised to choose three majors of graduate work in the Department of either Mathematics or Physics and six majors in the Department of Astronomy from courses numbered 5 to 10, 22, and 23. Those working for the Master's degree in Practical Astronomy or Astrophysics at the Yerkes Observatory are not required to spend part of their time at the University, although this is advised where possible.

The degree of Doctor of Philosophy.—The courses prescribed for the Master's degree together with three other graduate courses will meet the requirement for the Doctor's degree where Astronomy is the minor subject.

Candidates for the Doctor's degree, with Astronomy as major subject, are expected to take a number of courses in Mathematics and Physics. Students intending to specialize in Mathematical Astronomy will be required to take Advanced Integral Calculus, Differential Equations, and Theory of Functions of a Complex Variable; students intending to specialize in the lines of Astrophysics will be required to take the work in Theoretical Physics, Advanced Experimental Physics, Sound and Light, and Physical Manipulation. The courses in Astronomy which will be required depend on the phase of the subject which the candidate elects for his work. Students specializing in Mathematical Astronomy are expected to spend six months at the Yerkes Observatory, and those working in Practical Astronomy and Astrophysics are expected to spend at least two quarters at the University.

COURSES AVAILABLE FOR UNDERGRADUATES

SEQUENCES

3A and B, Descriptive Astronomy; 2, Spherical Trigonometry, with applications; 5, 6, Analytic Mechanics; 7A and B, Practical Astronomy; 10, Spectroscopy and Astrophysics; 22, 23, Celestial Mechanics; Mathematics 3, Analytic Geometry; 18, 19, Calculus; Physics 3, Mechanics, Molecular Physics, Heat; 4, Electricity, Sound, and Light.

The Department offers no nine-major sequences.

SECONDARY SEQUENCES

I. Astronomy

Courses 3A, 3B, 2, 7A, 7B, 10.

II. Astronomy and Mathematics

Courses 3, 18, 19, in Mathematics, 5, 6, 22, in Astronomy.

III. Astronomy and Physics

Courses 3A, 3B, Physics 3, 4, Astronomy 7, 10.

COURSES OF INSTRUCTION

A. JUNIOR COLLEGE COURSES

1. Descriptive Astronomy (shorter course).—An elementary course, dealing with fundamental facts, principles, and methods. Frequent access to the students' observatory. Mj. Summer, Assistant Professor MacMillan; Autumn, Professor Moulton; Spring, Professor Moulton and Assistant Professor MacMillan.

2. Spherical Trigonometry with Applications to Astronomy.—Prerequisite: Plane Trigonometry.

3A and 3B. Descriptive Astronomy (longer course; 1 not prerequisite).—A two-quarter course dealing with the fundamental facts and principles of Astronomy. Modern as well as classical methods and results are brought into full discussion. The observational side of the subject also is emphasized. Prerequisite: Plane Trigonometry. Mj. Winter and Spring, Assistant Professor MacMillan.

4. Introduction to Surveying (Mathematics 1).—Mj. Spring, Associate Professor Laves.

B. SENIOR COLLEGE COURSES

5. Analytic Mechanics (Statics).—An introductory course. Prerequisite: Mathematics 18, 19. Mj. Autumn, Associate Professor Laves.

6. Analytic Mechanics (Dynamics).—Prerequisite: Mathematics 18, 19. Mj. Winter, Associate Professor Laves.

7. Spherical and Practical Astronomy.—Determination of time, latitude, and longitude. Prerequisite: Astronomy 1 and Mathematics 3.

8. Practical Astronomy I.—Observations of binary stars and determination of their orbits.

9. Practical Astronomy II.—Observations of satellites and determination of orbits of satellites.

10. Spectroscopy and Astrophysics (Physics 24).—A non-technical treatment of the growth of Spectroscopy, with applications to solar and stellar phenomena.

C. GRADUATE COURSES

12. The Sidereal Universe.—Prerequisite: Astronomy 1. Mj. Summer and Winter, PROFESSOR MOULTON.

21. Advanced Mechanics.—Prerequisite: Mathematics 18, 19 Mj. Spring, ASSOCIATE PROFESSOR LAVES.

22. Introduction to Celestial Mechanics I.—Gravitational theory of sun's heat, central forces, potential and attraction of finite bodies, properties of conic section motion. Prerequisite: Mathematics 18, 19. Mj. Summer and Winter, ASSISTANT PROFESSOR MACMILLAN.

23. Introduction to Celestial Mechanics II.—Determination of orbits, special cases of the problems of three bodies: the Lunar Theory geometrically considered; variation of the elements and absolute perturbations. Mj. Spring and Summer, ASSISTANT PROFESSOR MACMILLAN.

31–36. Research Courses at the Yerkes Observatory.—The Yerkes Observatory is open only to graduate students who have completed the necessary preliminary studies and have had the requisite experience in practical laboratory and observatory work. Students wishing to work at the Observatory should first consult the Director of the Yerkes Observatory, Williams Bay, Wis., and obtain his approval. DMj. or 3Mjs. each Quarter, PROFESSORS AND INSTRUCTORS resident at Yerkes Observatory.

41. Theory of Planetary Motion.—Prerequisite: Astronomy 22 and 23. Mj. Autumn, PROFESSOR MOULTON. [Not given in 1919–20.]

42. The Lunar Theory.—Prerequisite: Astronomy 22 and 23, Mathematics 121. Mj. Winter, PROFESSOR MOULTON. [Not given in 1919–20.]

43. Application of the Methods of Periodic Orbits to the Lunar Theory.—Prerequisite: Astronomy 42. Mj. Spring, PROFESSOR MOULTON. [Not given in 1919–20.]

44. Solution of Numerical Differential Equations.—Mj. Summer, PROFESSOR MOULTON.

45. Exterior Ballistics.—Mj. Autumn, PROFESSOR MOULTON.

51, 52. Modern Theories of Analytic Differential Equations with Applications to Celestial Mechanics and Periodic Orbits I, II.—Properties of the solution of a general system of differential equations of the nth order as functions of the independent variable, of the parameters, of the initial values of the dependent variables. Solutions developed as power series in the independent variable, in the parameters, in the initial values of the dependent variables, by the Cauchy-Lipschitz process, by the Picard approximation process, by continued variation of parameters. Applications to elliptic and hyperelliptic functions and to periodic solutions of the problem of three bodies. Linear equations with applications to hypergeometric functions. Linear equations with periodic coefficients. Mj. Autumn and Winter, PROFESSOR MOULTON.

60. Periodic Solutions of the Problem of Three Bodies.—Mj. PROFESSOR MOULTON. [Not given in 1919–20.]

70. Theory of Figures of Equilibrium of Rotating Fluid Bodies.—This is an advanced course, including Poincaré's and Darwin's researches. Mj. PROFESSOR MOULTON. [Not given in 1919–20.]

80. The Problem of Three Bodies.—Mj. PROFESSOR MOULTON. [Not given in 1919–20.]

THE DEPARTMENT OF PHYSICS

OFFICERS OF INSTRUCTION

Albert Abraham Michelson, Ph.D., Sc.D., LL.D., F.R.S., Professor and Head of the Department of Physics.
Robert Andrews Millikan, Ph.D., Sc.D., Professor of Physics.
Henry Gordon Gale, Ph.D., Professor of Physics.
Carl Kinsley, A.M., M.E., Associate Professor of Physics.
Harvey Brace Lemon, Ph.D., Assistant Professor of Physics.
‡Arthur Jeffery Dempster, Ph.D., Instructor in Physics.
Otto Koppius, S.B., Instructor in Physics.
Yoshio Ishida, Ph.D., Assistant in Physics.
Harold Horton Sheldon, A.M., Assistant in Physics.
Alfred H. Fischer, B.S., Assistant in Physics.
Andrew Merritt McMahon, M.S., Assistant in Physics.
Harry Campbell Thompson, B.S., Assistant in Physics.
Garvin Dennis Shallenberger, A.B., Assistant in Physics.

FELLOWS, 1919–20

Edward Stowe Akeley, A.B.
Edward Blankenstein, S.B.
Edward Theodore Johnson, S.B.
John Preston Minton, S.B.
James Byron Friauf, A.B.

INSTRUCTIONAL WORK

The instructional work in Physics is directed toward the following ends: (1) the training of original investigators in physics; (2) the training of men competent to fill college and university positions as teachers of physics; (3) the training of teachers of physics for secondary schools; (4) the training of pre-engineering and premedical students for later professional work; (5) the training of the general student in scientific methods of work and in the understanding of the place of physical science in the modern world. From the most elementary to the most advanced courses the laboratory and the problem method of instruction are emphasized.

FACILITIES

The Ryerson Physical Laboratory has been enlarged and remodeled with especial reference to offering the best facilities for research work. The entire lower floor and basement are given up to private research-rooms. A well-equipped shop, with skilled instrument-makers, furnishes opportunity for the construction of special pieces of research apparatus. The equipment has been selected with reference to the needs of research, and includes spectroscopic instruments of highest power, electrical apparatus for work in alternating and direct currents through all ranges of potential, and appliances for high- and for low-temperature work, including a liquid-air plant. The library of the Department is well equipped for research purposes. A Physics Club is conducted by the members of the Department, and meets regularly for the discussion of the results of research work done in the Ryerson Laboratory and elsewhere.

‡ Absent on leave.

COURSES AVAILABLE FOR UNDERGRADUATE SEQUENCES

3, Mechanics; 4, Electricity; 5, Heat, Sound, and Light; 3S, Mechanics, Molecular Physics, and Heat; 4S, Electricity, Sound, and Light; 7, Lecture Demonstrations in Physics; 9, Elementary Wireless Telegraphy; Mathematics 7, 8, 9, Applied Mathematics (see under Mathematics Department); 11, Heat and Molecular Physics; 12, Light; 13, Electricity and Magnetism; 14, Pedagogy of Physics; 15, Mechanics and Wave-Motion; 16, 17, 18, 19, Experimental Physics; 20, Physical Manipulation; 21, Analytic Mechanics (Astronomy 5, 6); Education 62, Educational Psychology; 1, Principles of Education; Astronomy 3, Descriptive Astronomy (two majors); Mathematics 18, 19, Calculus.

Graduate courses in the Department may be substituted for courses 10 to 19 by students who have the prerequisites.

PRINCIPAL SEQUENCES

a) Courses 3, 4, 5, or 3S, 4S, 7, and any six majors chosen from courses 10 to 13; 15 to 19.

Physics and Mathematics

b) Courses 3, 4, 5, or 3S, 4S, 7, and any six majors from the following: Mathematics 18, 19; Astronomy 5, 6, and Physics 10 to 13; 15 to 18.

Teacher's Sequences

c) Courses 3, 4, 5, 7, or 3S, 4S, 7; 11, 14, 20; Education 62 and Philosophy 7.

Physics and Astronomy

d) Courses Physics 3, 4, 5, or 3S, 4S, 7; Astronomy 3 (two majors), with four majors selected from Physics 11–18, and Mathematics 18, 19.

Physics and Chemistry

e) Courses Physics 3, 4, 5, or 3S, 4S, 7; Chemistry 2S, 3S, and four majors selected from Physics 11–18, 18, and Mathematics 18, 19.

In any of the foregoing sequences graduate courses numbered 31 to 69 may be substituted for courses 10 to 18 by students who have the required prerequisites.

SECONDARY SEQUENCES

a) Courses 3, 4, 5, or 3S, 4S, 7, and three advanced majors in Physics.

b) Courses 3, 4, 5, or 3S, 4S, 7, and three majors from the following: 10 to 69, Astronomy 3 (two majors), Chemistry 2S, 3S; Mathematics 18, 19.

DEGREES

All candidates for the S.B. degree who elect their major work in Physics are required to take courses 3, 4, and 5, and either six majors selected from courses 10, 11, 12, 13, 15, 16, 17, 18, 19, 24, and 28, or three of these and three Senior College courses in one of the following departments: Mathematics, Astronomy, Chemistry, Geology, or Geography.

The Master's degree.—Candidates for the Master's degree in Physics are required to take eight majors in Physics and related subjects, and to present in addition a dissertation embodying the results of a laboratory problem. All courses in the Department numbered 10 or above, except course 20, will be counted in satisfaction of this requirement, but at least three majors selected from courses 10, 11, 12, 13, and 15 must be included.

The degree of Doctor of Philosophy.—Candidates for the Doctor's degree with Physics as a minor subject must take six of the following courses: 10, 11, 12, 13, 15, 16, 17, 18, 19, 24, 28, and three additional majors of graduate work. When Physics is one of two minor subjects, the courses must be arranged by consultation with the Department.

All candidates for the Doctor's degree with Physics as the major subject must take the following courses: 10, 11, 12, 13, 15, and 28, or their equivalent; three majors selected from courses 16, 17, 18, 19, 37, 38; courses 31–36, and three additional graduate courses selected by the student. Each candidate must also present a dissertation embodying the results of original research in some subject approved by the Department. The time required for the dissertation work generally varies from three to six quarters.

PREPARATION FOR TEACHING

Students preparing to teach Physics in secondary schools are expected to have completed courses 3, 4, 5, 14, 28, and not less than four of courses 10, 11, 12, 13, 15, 16, 17, 18, 19, and 24. See also courses in Physics in the School of Education.

LABORATORY FEE

There is a laboratory fee of $5.00 for all major courses involving laboratory work in the Department of Physics.

COURSES OF INSTRUCTION

I. JUNIOR COLLEGE COURSES

1. Elementary Physics.[1]—A first course in the elements of Physics designed primarily for students who do not present entrance Physics. Prerequisite: Algebra and Plane Geometry, one unit each. DM. Summer, First Term, Mr. Fischer; Mj. Autumn, Mr. Fischer.

2. Elementary Physics.[1]—A continuation of the preceding course, covering the subjects of electricity, sound, and light. Prerequisite: course 1. DM. Summer, Second Term, Mr. Fischer; Mj. Winter, Mr. Fischer.

3. Mechanics.—A general college course in mechanics presented mainly from the experimental point of view, but including one demonstration lecture each week. Prerequisite: entrance Physics or course 2. Mj. Autumn, 5 sections, Assistant Professor Lemon, Mr. Koppius, Mr. McMahon, and Mr. Shallenberger.

4. Electricity.—A general college course in electricity, presented mainly from the experimental point of view, but including one demonstration lecture each week. Prerequisite: course 3. Mj. Winter, 4 sections, Assistant Professor Lemon, Mr. Koppius, Mr. McMahon, and Mr. Shallenberger.

5. Heat, Sound, and Light.—A general college course in heat, sound, and light, presented mainly from the experimental point of view, but including one demonstration lecture each week. Prerequisite: course 4. Mj. Spring, 3 sections, Assistant Professor Lemon, Mr. Koppius, Mr. McMahon, and Mr. Shallenberger.

[1] Limited-credit course: After a student has credit for 18 majors but less than 27, these courses will be credited at one-half major each; after he has credit for 27 majors they will not be credited at all.

3S. Mechanics, Molecular Physics, and Heat.—A general college course in mechanics, molecular physics, and heat presented from the experimental point of view, not containing demonstration lectures. Prerequisite: entrance Physics or course 2 and Trigonometry. Mj. Summer, 2 sections, Mr. Watson, Mr. Shallenberger; Winter, 4 sections, Mr. Koppius, Mr. Thompson, Mr. McMahon, and Mr. Sheldon.

4S. Electricity, Sound, and Light.—A general college course in electricity, sound, and light presented from the experimental point of view, not containing demonstration lectures. Prerequisite: course 3S or courses 3 and 4. Mj. Summer, 2 sections, Dr. Hagenow; Spring, 3 sections, Mr. Koppius, Mr. Thompson, and Mr. Sheldon.

7. Lecture Demonstration Course.—A course of demonstration lectures covering the entire field of Physics designed to supplement courses 3S and 4S. Especial attention is given to modern points of view; the kinetic theory of heat, the atomic theory of electricity, and the electrical theory of matter receiving especial attention. The attempt is made to repeat a majority of the classical demonstrations of Kelvin, Faraday, Thomson, and others. This course includes the demonstration lectures of courses 3, 4, and 5. Prerequisite: courses 3S and 4S or their equivalent. Mj. Summer, Mr. Koppius.

9. Elementary Wireless Telegraphy.—A course of lectures and laboratory work consisting of elementary consideration of the fundamental laws and their applications to the circuits of modern wireless telegraph systems. Experimental adjusting of wireless telegraph circuits and practice in receiving the Continental code. Prerequisite: courses 3 and 4. Mj. Summer and Autumn, Associate Professor Kinsley.

Applied Mathematics I, II, III.—An intensive training course in mathe matical methods for students who expect to undertake scientific work; in close connection with corresponding courses offered by the Departments of Physics and Chemistry. Students desiring to begin intensive training in Physics for future scientific service should register for these three courses which are designed to prepare them for Senior College work in Physics (see Mathematics 7, 8, 9, for more detailed announcement). Three consecutive majors.

II. SENIOR COLLEGE COURSES

10. Elementary Mathematical Physics.—A lecture course on the application of Elementary Calculus to Physics and Chemistry, and practice in the solution of problems. Prerequisite: Physics 4S or 5 and not less than one major of Calculus. Mj. Autumn, Professor Gale.

11. Heat and Molecular Physics.—A lecture course for advanced and graduate students, covering the Kinetic Theory, Capillarity, Elementary Thermodynamics, Solution, and Electrolysis. Prerequisite: Physics 4S or 5 and Calculus. Mj. Autumn, Professor Millikan.

12. Light.—A lecture course for advanced students covering the more important sections of geometrical and physical optics. Prerequisite: Physics 4S or 5 and Calculus. Mj. Winter, Professor Gale.

13. Electricity and Magnetism.—A course of advanced work in Theoretical Electricity and Magnetism, with many applications to electrical and magnetic apparatus and measurements. Prerequisite: Physics 4S or 5 and Calculus. Mj. Winter, Associate Professor Kinsley.

14. The Pedagogy of High-School Physics.—This course includes the following topics: the present high-school course in Physics, its development, requirements, and methods of presentation; the principles involved in the lecture demonstration, in the recitation and quiz, and in the laboratory experiments and notebook. The course is illustrated by a series of lecture demonstrations. It provides a survey of the whole field of Physics, with a special reference to the

choice of subject-matter and effective methods of presentation in high-school classes. Prerequisite: a thorough knowledge of the first principles of Physics. Lecture, 9:00; Laboratory, 7:00. DMj. Summer.

15. Mechanics and Wave-Motion.—A lecture course on the physical meaning and the mathematical derivation of the fundamental equations of Mechanics and Wave-Motion. Prerequisite: Physics 4S or 5 and Calculus. Mj. Spring, PROFESSOR GALE. [Not given in 1919–20.]

16. Experimental Physics (Advanced): Molecular Physics and Heat.—A course of advanced laboratory work involving the determination of vapor pressures and densities, coefficients of friction of gases and liquids, molecular electrical conductivities, freezing- and boiling-points, latent and specific heats, high and low temperatures, radioactive constants, etc. Prerequisite: course 4S or 5. Summer, PROFESSOR MILLIKAN AND MR. WATSON; Mj. Spring, PROFESSOR MILLIKAN AND DR. DEMPSTER.

17. Experimental Physics (Advanced): Light.—A course of advanced laboratory work in Light, consisting of accurate measurements in diffraction, dispersion, interference, and polarization. Prerequisite: course 4S or 5. Mj. Summer and Autumn, PROFESSOR GALE.

18. Experimental Physics (Advanced): Electricity and Magnetism I.—Laboratory work of the same grade as courses 16 and 17, but consisting of measurements in Electricity and Magnetism. Prerequisite: Physics 4S or 5. Mj. Winter, ASSOCIATE PROFESSOR KINSLEY.

19. Experimental Physics (Advanced): Electricity and Magnetism II.—Laboratory work accompanied by lectures consisting of the theory and operation of dynamos, motors, transformers, wireless-telegraph apparatus. Prerequisite: Physics 4S or 5. Mj. Spring, ASSOCIATE PROFESSOR KINSLEY.

20. Physical Manipulation.—A series of exercises not provided in the regular courses of Experimental Physics, but important to the teacher or advanced student. It consists of the following groups:

Group A. *Shopwork* includes the cutting, filing, drilling, tapping, soldering, and polishing of metal, screw-cutting, and elementary lathework.

Group B. *Glasswork* includes the cutting, grinding, drilling, polishing, and testing of glass.

Group C. *Glass-Blowing* includes the simpler processes in glass-blowing, such as cutting, bending, and joining of tubes, blowing bulbs, sealing in electrodes, etc.

Group D. *Chemical Processes and Physical Preparations* include the silvering of glass, cleaning and distillation of mercury, preparation of fibers for suspension, and materials useful in experimental work. Group C only M. First Term. Repeated Second Term, Summer, DR. ISHIDA.

21. Radioactivity and Discharge through Gases.—A laboratory course for Senior College and Graduate Students. Autumn, DR. DEMPSTER.

24. Spectroscopy and Astrophysics.—A non-technical treatment of the growth of Spectroscopy, with applications to solar and stellar phenomena. Prerequisite: 15 majors. Mj. Spring, PROFESSOR GALE. [Not given in 1919–20.]

27. Units and Dimensions.—The theory of units and dimensions as applied to the measurement of concrete magnitudes and the mathematical transcription of physical experiments. Physical similitude and the interpretation of models. Numerical computations and the reduction of observations. Prerequisite: General Physics and some knowledge of Calculus. Mj. Summer, 7:10, ASSOCIATE PROFESSOR LUNN.

28. Photographic Processes.—Lectures and laboratory work on the laws of photographic action. Effects of exposure and development on opacity and density; orthochromatism, plate grain, speed, intensification, reduction, and the applications of these to the photography of exceptional subjects. Prerequisite: Calculus. Mj. Spring, ASSISTANT PROFESSOR LEMON.

III. GRADUATE COURSES

31, 32, 33. Theoretical Physics.—A series of lectures chiefly in Theoretical Physics, Hydrodynamics, Elasticity, Capillarity, Molecular Physics, Thermodynamics, Wave-Motion, Sound, Optical Theories, Electricity, and Magnetism. 4 hours a week. Prerequisite: Physics 10, 11, and 13 and Calculus. Mj. Autumn, Winter, and Spring, PROFESSOR MICHELSON.

34, 35, 36. Theoretical Physics.—A series of lecture courses. Alternating with 31, 32, and 33. Prerequisite: same as for course 31. 3Mjs. Autumn, Winter, and Spring, PROFESSOR MICHELSON.

37, 38, 39. Experimental Physics.—A course of laboratory work, chiefly devoted to the repetition of classical experiments, such as Determination of the Mechanical Equivalent of Heat; Maxwell's "V"; Hertzian Oscillations; Relative and Absolute Wave-Lengths, etc. 10 hours a week. Prerequisite: Physics 16, 17, and 18. 3Mjs. Autumn, Winter, and Spring, PROFESSORS MICHELSON, MILLIKAN, GALE, AND KINSLEY.

40, 41, 42, 43. Research Course.—This course is intended for graduate students who are prepared to undertake special research. Except in the case of a purely mathematical problem, the entire time is to be devoted to work in the laboratory. DMj. Autumn, Winter, and Spring, PROFESSORS MICHELSON, MILLIKAN, GALE, KINSLEY, AND LEMON.

***45. Aëronautics 1.**—A course of lectures accompanied by a few demonstration experiments on the mechanical principles of flight. Dynamic similitude, elementary aërodynamics of fluid resistance, and the classical theory of Rayleigh form the principal theoretical topics. Much time is given to the discussion of the experimental work of Eiffel and the National Physical Laboratory on flat and cambered aërofoils, lift and drift coefficients. The Phugoid theory of Lanchester, longitudinal lateral and directional stability are taken up, as well as the modern gyroscopic devices of control. Prerequisite: Calculus and Elementary Mechanics, or consent of instructor. Mj. Winter, ASSISTANT PROFESSOR LEMON.

48. Spectrometry I.—Laboratory work in photographing and measuring the spectra of various elements. Use of the concave grating, echelon, and interferometer. Prerequisite: consent of the instructor. Mj. Winter, PROFESSOR GALE.

51. Thermodynamics.—Lectures upon the fundamental principles underlying the mechanical theory of heat and the application of these principles to physical and thermochemical problems. Prerequisite: two years of college Physics and Calculus. 5 hours a week. Mj. Summer, Winter, ASSOCIATE PROFESSOR LUNN.

52. Electron Theory I.—A course of graduate lectures covering the work of the last twenty years on the electrical properties of gases, the electron theory, and radioactivity. Prerequisite: same as for course 51. 5 hours a week. Mj. Summer, PROFESSOR MILLIKAN.

53. Electron Theory II.—A continuation of 52, dealing with the application of the electron theory to metallic conduction, to the Seebeck, Peltier, Thomson, and Hall effects, to optical phenomena in magnetic fields, to the subject of electromagnetic mass, etc. 5 hours a week. Mj. PROFESSOR MILLIKAN. [Not given in 1919–20.]

55. Atomic Theories of Radiation and Their Experimental Basis.—A course of graduate lectures on recent theories of radiation, with especial reference to their relations to the laws of thermodynamics. Prerequisite: Elementary Thermodynamics. Mj. Spring, PROFESSOR MILLIKAN.

56. X-Rays and Theories of Atomic Structure.—A course of graduate lectures dealing with X-rays and the related phenomena, the study of which has thrown new light upon the structure of the atom and the relations of the atom and the molecule. Prerequisite: College Physics and Calculus. PROFESSOR MILLIKAN. [Not given in 1919–20.]

58. Transient Electrical Phenomena.—Theory and demonstration of current flow before the steady state is reached. Oscillations in power circuits and wireless-telephone and -telegraph transmission are discussed. Prerequisite: course 18 or 19 and Calculus. Mj. Spring and Summer, ASSOCIATE PROFESSOR KINSLEY.

59. Modern Spectroscopy.—A lecture course on the theory and use of spectroscopic apparatus and a discussion of spectroscopic and astrophysical phenomena. Prerequisite: same as course 51. Mj. Summer, PROFESSOR GALE.

60. Light Waves and Their Uses.—A course of graduate lectures on recent developments in physical optics. Prerequisite: same as for course 51. Mj. PROFESSOR MICHELSON. [Not given in 1919–20.]

62. The Theory of Relativity.—After a brief historical introduction on the notion of relativity of time and space in its classic or Newtonian form, the course will be devoted to a study of the recent theory initiated by Einstein and Minkowski as a geometry of space and time adapted to the representation of physical laws. Special attention will be given to the discrimination between the logical elements of the theory and the special concrete interpretations that may be used in the formulation of experimental results. Mj. Summer, ASSOCIATE PROFESSOR LUNN.

63. Geometrical Optics.—The methods and principles of Geometrical Optics as applied to the designing of optical instruments and the interpretation of their performance. Theory of the ideal instrument and its approximate realization; aberrations; illumination and diffraction; special properties of particular instruments; characteristics of various types of optical glass. Mj. Spring, ASSOCIATE PROFESSOR LUNN.

64. Electromagnetic Theory.—(*a*) The main experimental facts of electromagnetism and their generalization so far as covered by the Maxwell theory in its abstract form; special problems concerning steady fields, induction, and electromagnetic waves. M. First Term, Summer; (*b*) The electronic interpretation and extension of the Maxwell theory; electromagnetic mass; theory of radiation and conduction; problems relating to moving bodies. Mj. Winter, ASSOCIATE PROFESSOR LUNN.

65. Theory of Wireless Telegraphy.—The fundamental laws and their application to the wireless telegraph circuits of the various operating systems. Prerequisite: Physics 13, 18, or 19 and Calculus. ½Mj. Winter, MR. DEMPSTER AND MR. LAMSON.

66. Electrical Measurements in Wireless Telegraphy.—Experimental verification of wireless telegraph theories and the measurement of constants at high frequencies. Prerequisite: registration in 65. ½Mj. Winter, MR. DEMPSTER.

68. Theory of Sound.—Dynamical theory of production; transmission and reception of sound. Analysis and systems of vibrations. Illustrations by acoustic apparatus and musical instruments. Analogies in electromagnetic oscillations. Mj. Winter, ASSOCIATE PROFESSOR LUNN. [Not given in 1919–20.]

69. Physical Optics.—A theoretical treatment of optical phenomena in the realm of interference and diffraction. M. First Term, Summer, PROFESSOR MICHELSON.

70. Physics Club.—This organization, consisting of all instructors and graduate and advanced students in the Department, meets on Thursday of each week from 4:30 to 6:00 for the discussion of recent research.

THE DEPARTMENT OF CHEMISTRY

OFFICERS OF INSTRUCTION

JULIUS STIEGLITZ, PH.D., SC.D., CHEM. D., Professor and Chairman of the Department of Chemistry.
WILLIAM DRAPER HARKINS, PH.D., Professor of Chemistry.
HERMANN IRVING SCHLESINGER, PH.D., Associate Professor of Chemistry.
*JEAN FELIX PICCARD, SC.NAT.D., Associate Professor of Organic Chemistry.
ETHEL MARY TERRY, PH.D., Assistant Professor of Chemistry.
JOHN WILLIAM EDWARD GLATTFELD, PH.D., Assistant Professor of Chemistry.
GERALD LOUIS WENDT, PH.D., Assistant Professor of Chemistry.
‡LEO FINKELSTEIN, S.B., Instructor in General Chemistry.
FRANK L. DE BEUKELAER, A.B., A.M., Instructor in Chemistry.
‡WILLIS EUGENE GOUWENS, Curator.
MARY MEDA RISING, A.B., Associate in Chemistry.
MARY WETTON, S.B., Associate in General Chemistry, Summer.
FREDERICK F. BLICKE, S.B., S.M., Research Associate. Lieutenant, Chemical Warfare Service, Washington, D.C.
THOMAS HARRISON LIGGETT, PH.B., S.M., Assistant in Physical Chemistry.
KARL STEIK, S.B., Assistant in Organic Chemistry.
‡LATHROP EMERSON ROBERTS, S.B., Assistant in General Chemistry.
IDA KRAUS, S.B., Assistant in Quantitative Analysis.
LILLIE EICHELBERGER, S.B., Assistant in Chemistry.
EVERETT BOWDEN, S.B., S.M., Assistant in Chemistry.
PHILENA YOUNG, A.B., Assistant in Chemistry.
HENRY MAY MCLAUGHLIN, B.S., A.M., Assistant in Chemistry, Summer.
GLADYS LEAVELL, S.B., Assistant in Chemistry, Summer.
RALPH W. GERARD, Assistant in Qualitative Analysis.
GRANT KLOSTER, S.B., Lecture Assistant.
MARION G. FRANK, S.B., Lecture Assistant.

CHARLES A. KRAUS, PH.D., Professor of Chemistry, Clark University (Summer, 1919).
ZONJA WALLEN, S.B., Associate Professor of Chemistry, Mount Holyoke College (Summer, 1919).

FELLOWS, 1919–20

NORVIL BEEMAN, A.B.
HENRY LEON COX, S.B.
FRANK LOUIS DE BEUKELAER, A.M., Du Pont Fellow.
MARTIN CHARLES EDWARD HANKE, S.B.
ROBERT SANDERSON MULLIKEN, S.B., Loewenthal Fellow.
LATHROP EMERSON ROBERTS, S.B., Swift Fellow.
ALBERT J. SALATHE, A.B.
MARGUERITE FITCH WILLCOX, S.B., Edith Barnard Fellow.

* Resigned.
‡ Absent on leave.

INSTRUCTIONAL WORK

The Department aims to prepare students (1) for government and war service, (2) to teach in colleges or universities, (3) to teach in secondary schools, (4) to fill positions as technical experts or assistants in chemical industries, (5) to become analysts in commercial and sanitary laboratories. The elementary courses may be taken with advantage by students having none of these ends in view.

Special stress will be placed on thoroughness of preparation and the symmetrical development of the student's knowledge. The object of the courses will be not so much to train specialists as to prepare the student to undertake intelligently all kinds of work of a chemical nature. Those intending to become practical chemists will find a thorough course of purely scientific chemistry the best basis for future specialization in any branch of the subject. Those who incline toward inorganic chemistry will be required to do much physical and a considerable amount of organic work; those proposing to become organic chemists will be required to do work in inorganic chemistry of a more advanced nature than that given in the elementary and analytical courses, and some physical chemistry, etc. The test of time and the experiences of the graduates of the Department have fully justified this form of training.

RESEARCH

Students are encouraged to begin research work as soon as their preparation justifies it. Facilities for research in all lines, whether of inorganic, organic, radioactive, or physical chemistry, are provided. Special opportunities to pursue entirely independent research work, as guests of the University (see p. 10), will be given to maturer students who have already obtained the Doctor's degree. Besides a number of general University Fellowships which are usually allowed to the Department for candidates for the Ph.D. degree, there are five specially endowed Fellowships in Chemistry: the Loewenthal Fellowship, a memorial to Joseph B. Loewenthal; the Swift Fellowship, endowed by Mrs. Gustavus F. Swift; the Edith Barnard Fellowship, a memorial to Edith Ethel Barnard, a former instructor, donated by her friends and family; the DuPont Fellowship, granted by the E. I. du Pont de Nemours Company; the Hoskins Fellowship, donated by William Hoskins.

ARRANGEMENT OF COURSES

1, 2, 3, 2S, 3S, General Chemistry, Inorganic; 4, Elementary Organic; 6, 7, 10, Qualitative Analysis; 8, 9, 11–19, Quantitative Analysis; 20–22, Elementary Physical Chemistry; 25, Toxicology; 26, Detection of Poisons; 30–49, Organic Chemistry; 50–59, Advanced Inorganic Chemistry; 60–74, Advanced Physical Chemistry; 75–79, Radio-Chemistry; 83, Teaching of Chemistry; 90–101, Research.

REQUIREMENTS FOR DEGREES

THE DEGREE OF DOCTOR OF PHILOSOPHY

I. *Chemistry the primary subject.*—When the degree of Doctor of Philosophy in Chemistry is desired, the branch of chemistry touched by the dissertation is offered as a *major subject* and some other branch of chemistry as the *first minor*

subject. Besides this, a sufficient knowledge of other fundamental phases of the science is required as well as sufficient work in a *second minor* subject in some other department. These conditions are complied with when the following specific requirements are fulfilled:

1. The presentation of a dissertation embodying the result of original research in General, Inorganic, Organic, Physico-organic, or Physical Chemistry, or Radioactivity. This must constitute a real contribution to knowledge, and the work is usually done under the direction of an officer of the Department.

2. The general requirements for all candidates, in advance of General Chemistry: courses 4,[1] 6–9, 20, and two majors selected from courses 10, 11, 13–19, 21–22, 30–34.

3. In addition to the above, one of the following specific sets of requirements, arranged according to the thesis subject:

General Chemistry and Inorganic Chemistry: courses 21, 22, 35 (or 30 and 31), 50, 51 and 52 or 63, and one major taken from courses 13–19, 30–37, 52, 63; *Organic Chemistry:* courses 30–32, 35[2]–37, and one major from 10, 13–19, 51, 52, 31, 21, 22, 54; *Physico-organic Chemistry:* courses 30–32, 35[2], 21, and 22, 36 or 50, and one major taken from courses 10, 13–19, 51, 52, 63, and 64. *Physical Chemistry:* courses 21, 22, 35 (or 30 and 31), 50, 36 or 51, 63, 22, and one major taken from courses 10, 13–19, 30–32, 35–37, 52. *Radioactivity* or *Photo-Chemistry:* courses 21, 22, 50, 63, 76, and Physics 52 (Electron Theory), and one major taken from courses 10, 13–19, 22, 30–32, 35–37, and 52. In addition to one set of these specific requirements at least six half-majors will be chosen from the special lecture course 41–46, 54–59, 65–79, 83. The research work will require from four to six quarters.

4. Sufficient work of an advanced character in another department to make a *second minor* of *three majors.* In addition to the regular minor subject, candidates are advised to take Mineralogy and Crystallography. The following are the requirements for such a minor in various departments: (*a*) In *Physics:* three of the courses 11, 12, 13, 16, 17, 18, 19, 48, 49, 51, 52, 53, 55 or 56; courses 3, 4, 5 are prerequisite to these. (*b*) In *Physiological Chemistry:* three majors selected from 19, 20, 24, 25, 37, 38, 39, or 42. (*c*) In *Geology:* courses 15, 16, and 52 or their equivalent. Courses 7 or 8, and 11, 12, 14 would be prerequisite to these courses. (*d*) In *Geography:* courses 17, 18, 21, and their prerequisite courses. (*e*) In *Hygiene and Bacteriology:* course 12 and two and one-half majors in course 15; courses 2 and 3 are prerequisite to these. With permission, course 10 or 11 may be substituted for course 12.

II. *Chemistry the secondary subject.*—When Chemistry is a secondary subject, the requirement is determined after conference with the Head of the Department in which the major work is done. Courses 6, 7, and 8, and six other majors in advance of 8, will be required when Chemistry is the only secondary subject; courses 6, 7, and 8, and three other majors, when Chemistry is one of two secondary subjects. Elementary Physical Chemistry or Organic Chemistry, according as the major subject belongs to the Physical or the Biological Group, is recommended.

[1] Course 4 may be omitted when advanced work in Organic Chemistry is taken.

[2] Course 35 will be omitted when courses 30–31 have included laboratory work.

THE MASTER'S DEGREE

For the Master's degree in Chemistry a dissertation and eight majors of graduate work in Chemistry are required if all the work is in Chemistry. These majors must be selected from courses in advance of 9, with the approval of the Chairman of the Department. Courses prerequisite to these must be taken, but cannot be counted in reckoning the eight required majors. At least one course in Physical Chemistry and one in Organic Chemistry must be included in the courses taken if they have not been taken before.

Chemistry courses given in the Departments of Physiological Chemistry, Geology, and Home Economics may be included in these eight majors.

The eighth major of graduate work will be devoted to specific preparation (in residence) for the dissertation, either in the laboratory (research) or in the library (historical work), under the direction of some instructor chosen by the candidate.

Courses leading to the doctorate and Masters' degrees in the Chemistry of Nutrition are given in the Department of Home Economics in conjunction with other departments.

THE DEGREE OF BACHELOR OF SCIENCE

Chemistry may be taken as a major subject to fulfil the requirement for a principal sequence or as a minor subject to fulfil the requirement for a secondary sequence. Guidance as to a more thorough preparation in college for professional work in Chemistry is given below (p. 41).

I. PRINCIPAL SEQUENCES

1) Courses 2, 3 (or 2S, 3S), 4, 6, 7, 8, 9, 20, and any other course in the Department except 1. If courses 33 and 34 or courses 30 and 31 be taken, course 4 is not required.

2) Combination with other science departments: By dropping the necessary majors from the latter portion of sequence 1) above, nine major sequences may be offered involving the following courses: (1) three majors in College Physics, i.e., 3, 4, 5 (3S, 4S), but not 1, 2, preceding or accompanying six Chemistry courses enumerated in 1) above; (2) one to three majors in Geology selected from Geology 2, 3, 11, 12, 40–45, 50, 52, 53, when these courses follow Chemistry courses 2, 3 (or 2S, 3S), and 6; (3) two majors of Physiological Chemistry, provided they are taken after courses 2, 3 (2S, 3S), 4, and 6 in Chemistry; (4) two majors in Chemistry of Foods and Dietetics, provided these courses follow 2, 3 (2S, 3S), 4, and 6 in Chemistry.

II. SECONDARY SEQUENCES

a) For students specializing in Physics: courses 2, 3, 6, 7, 8, and either 4 or 9 or 20.

b) For students specializing in Biological Science: courses 2, 3, 4, 6, 7, and 8. In addition course 20 is recommended on account of the increasing application of physical chemistry in biological work.

c) For students specializing in Geology: courses 2, 3, 6, 7, 8, 9; the Department strongly advises courses 10, 14, and one major from courses 20, 21, 22.

SPECIAL STUDENTS

Special or unclassified students, not candidates for a degree, will be received, but in every case they will be required to give evidence, satisfactory to the instructors, that their previous training has been sufficient to enable them to derive full profit from the courses they propose to take.

PREPARATION FOR PROFESSIONAL WORK

GRADUATE WORK

1. *Preparation for Teaching in University and College Positions:* (*a*) For recommendations for major appointments in the larger universities and colleges only students who have taken the degree of Doctor of Philosophy will be considered to have had an adequate preparation. For certain university positions marked ability in research evidenced in the work for the degree will be considered essential. An academic career of real promise demands as never before research ability and training, which should give a man the broader viewpoint for the past and the future of his science, as well as the enthusiasm for his subject as a living science, which are the earmarks of the inspiring teacher. (*b*) For recommendations for chairs in Chemistry in smaller colleges, the preparation demanded for the Master's degree will for the present be considered sufficient.

2. *Preparation for Technical and Government Work:* Thorough scientific training in all branches of chemistry as required for the Doctor's degree forms the best preparation for a career as a chemical expert in any branch of chemical industry. With this preparation the principles and details of technical processes are quickly grasped, advances in industrial processes are intelligently followed, and newly discovered principles are readily applied. A broad preparation, including advanced work in physical chemistry and mathematics for the candidate specializing in organic or inorganic chemistry, and vice versa, is strongly recommended.

All the more important requests received from technical establishments specify a doctorate of philosophy, with its training to do research work as a fundamental requirement.

For the more important government positions in Chemistry the doctorate of philosophy is generally demanded as an essential condition for candidacy.

UNDERGRADUATE WORK

I. For the college student who wishes to use his work for the Bachelor's degree as an opportunity for a thorough preparation for professional work in Chemistry, a careful and logical selection of his courses during the four years of his college work is invaluable in the interest of a broad and adequate preparation with a minimum of wasted effort. For the benefit of such a student the following outline of essential courses is given with an indication of the sequence in which these are best taken. Students taking this course will be given the preference, other qualifications being equal, in recommendations for appointments.

A. *General Outline of College Work*

1) *English*, 2 majors, required of all college students in their first year. (2) *Chemistry*, 15 to 18 majors, to be described below. The student should start

in his first year (Autumn or Summer) with Chemistry 1 or, if he has had high-school Chemistry, with 2S. (Entrance Physics is a prerequisite, and Physics 1 and 2 should be taken in the student's first two quarters if he has not had high-school Physics.) (3) *Physics*, 2 or 3 majors. Physics 3, 4, and 5 or 3S and 4S for students who have had Trigonometry. This work should be taken in the student's first or second college year. (Entrance Physics is a prerequisite, and Physics 1 and 2 should be taken in the student's first two quarters if he has not had high-school Physics.) (4) *Mathematics*, 3 majors (at least). The special sequence of courses, Mathematics 7 (Autumn), 8, and 9, covering college algebra, trigonometry, and elementary calculus, is recommended for the student's first or second year. Advanced work in Calculus is desirable. (5) *German*, 3 majors (or two years of high-school German). A knowledge of scientific German is greatly to be desired for advanced work in Chemistry. The student is advised to take the German in his *second* (not in his first year) or third college year, preferably as extra work. *French* may well be taken in the same way. (6) *Elective*. 7 to 11 majors, or more, if high-school work included Trigonometry, German, Physics, and Chemistry.

B. *Sequence of Fundamental Courses in Chemistry*

1) *General Inorganic Chemistry*, first year: 2S and 3S for students who have had high-school Chemistry, or 1, 2 and 3 for students who have not had admission Chemistry. Course 3 may be omitted in the case of very able students. (2) *Qualitative Analysis*, 2 majors, Courses 6 and 7. (3) *Quantitative Analysis*, 3 majors. Courses 8, 9, and a major from courses 13–19. (4) *Organic Chemistry*, 3 to 3½ majors. Course 4 and courses 30 (½ major, lectures, Autumn), 31, and 32, or courses 33, 34, and 32. (5) *Physical Chemistry* (third or, better, fourth year), 2 to 3 majors, beginning with course 20 (Autumn) or 20S (Summer). (6) *Elective*, 5 to 6 majors, to be taken in advanced courses in analytical chemistry (10–19), organic chemistry (35–37 and special lectures), inorganic chemistry (50–52 and special lectures), physical chemistry (22, 63, and special courses), radioactivity, courses 75–79, physiological chemistry (physiological chemistry 19, 20), chemistry of nutrition or bacteriology (1, 2, 3), with a view to specialization in one of these branches. Students are advised to consult very freely and early in their course with a Departmental Adviser, whose name may be secured at the Dean's office or at the office of Kent Chemical Laboratory, Room 19.

II. 1. *Preparation for Teaching:* For recommendations for minor appointments in universities and colleges the work represented by the principal sequence of 9 majors in Chemistry required for the Bachelor's degree (see p. 40), supplemented by from three to eight majors of advanced work in Chemistry, as outlined above, will be considered an adequate preparation.

The work represented by the principal sequence of 9 majors in Chemistry, required for the Bachelor's degree, is at present considered preparation for teaching in secondary schools. Some work in the College of Education is recommended. Men will find it advisable to be prepared also to teach Physics, Mathematics, or Geology. Women will find it wiser to combine Chemistry with Home Economics, Physics, Physiography, Physiology, Botany, or Zoölogy.

2. *Preparation for Technological Work:* Students who have taken from ten to eighteen majors of work in the Department, as outlined above, are able to fill satisfactorily positions as assistants in technical and analytical laboratories

and, after some practical experience, to advance to positions of independent responsibility.

3. *Preparation for Government Work:* For minor positions (e.g., junior chemist in the United States service) the Bachelor's degree is considered sufficient. The principal sequence in Chemistry, required for the degree, should be supplemented by *advanced* work in two or three branches of Chemistry (Inorganic, Organic, Physical, Analytical). If possible, the full course outlined under A and B should be taken.

The Department does not pledge itself to secure positions for those who have carried out any one of the above recommended sets of courses; but, as a matter of fact, competent students find suitable places quickly, and in the past the demand for chemists has far exceeded the supply, particularly in the case of the *more completely* trained graduates and Ph.D.'s.

CHEMICAL SOCIETIES

The Kent Chemical Society is a club of students open to all those who have had six majors of Chemistry. The Society meets biweekly to listen to papers by members and others.

The Chicago Section of the American Chemical Society holds monthly meetings (except in summer) which the students of the University are welcome to attend. Membership in the Society is open to advanced students at special rates.

LABORATORY FEE

There is a laboratory fee of $5.00 per major for all courses involving laboratory work in the Department of Chemistry. A deposit of $5.00 for breakage is also required of each student.

COURSES OF INSTRUCTION

NOTE.—After course 9, the courses are arranged in groups according to subjects: courses 10–19 include courses in Analytical Chemistry, 20–24 in Elementary Physical Chemistry, 25–49 in Organic Chemistry, 50–59 in Inorganic Chemistry, 60–74 in Physical Chemistry and Radioactivity; 80–89 are general in nature, and 90–101 are research courses. Nos. 75–79, 30–34, and 40–43 are open to, and suitable for, Senior College students.

I. PRIMARILY FOR THE JUNIOR COLLEGES

1. Elementary General Chemistry: Inorganic I.[1]—Prerequisite: preparatory Physics. DM. Summer, First Term. Classroom, 6 hours a week; laboratory, 12 hours a week, ASSISTANT PROFESSOR TERRY. Mj. Autumn. Classroom, 3 hours a week; laboratory, 6 hours a week, ASSISTANT PROFESSOR TERRY.

2. General Chemistry: Inorganic II (continuation of course 1).—Prerequisite: course 1. DM. Summer, Second Term, ASSISTANT PROFESSOR TERRY. Mj. Winter, ASSISTANT PROFESSOR TERRY.

NOTE.—Course 2, Winter Quarter, is a continuation of course 1, but may be entered by those having credit for admission Chemistry.

[1] Limited-credit course: After a student has credit for 18 majors but less than 27, these courses will be credited at one-half major each; after he has credit for 27 majors they will not be credited at all.

3. General Chemistry: Inorganic III (continuation of course 2). Prerequisite: course 2. Mj. Spring, ———.

NOTE.—Courses 1, 2, and 3 are consecutive courses. Separate credit is given for each, but students are advised not to take one course only. The aim of these courses is to give a definite idea of the fundamental principles of chemistry, and not to overburden the student with a mass of unconnected facts. The conception of chemical equilibrium and the modern theory of solutions are freely used. The lectures will be experimental to a considerable extent. The courses are designed to meet the wants, not only of those who wish to go deeper into chemistry, but of all who wish to study the science as part of a liberal education. The lectures and classroom work of 1, 2, and 3 may be taken by graduate students without the laboratory work or laboratory fee.

1C. Introduction to Modern Chemistry.—For non-professional students. Mj. Classroom work, 3 hours a week; laboratory work, 6 hours a week. Spring Quarter. PROFESSOR STIEGLITZ AND ———.

NOTE.—This course is intended for students who do not expect to use chemistry professionally but who wish to obtain a survey of the conceptions of chemistry as the fundamental science of the transformation of matter and of its significance in the life of the nation and in the development of civilization. Students preparing to take chemistry as a profession or in preparation for medicine or for other scientific applications will start with course 1, or, if they have had Preparatory Chemistry, with course 2S.

1N. Elements of Chemistry.—Primarily for student nurses. Classroom work, 3 hours a week; laboratory work, 4 hours a week. M. First Term, Autumn (1918), ASSOCIATE PROFESSOR SCHLESINGER; Spring (1919), MISS MARY RISING. Autumn, 1919, ———; Spring, 1920, ———.

2S. General Chemistry: Inorganic (first course).—For students who have had preparatory Chemistry. Prerequisite: preparatory Chemistry and preparatory Physics, one unit each. DM. Summer, First Term. Classroom, 6 hours a week; laboratory, 12 hours a week, MR. DEBEUKELAER; Mj. Autumn. Classroom, 3 hours a week; laboratory, 6 hours a week, ASSOCIATE PROFESSOR SCHLESINGER AND ———.

3S. General Chemistry: Inorganic (continuation of course 2S).—DM. Summer, Second Term, MR. DEBEUKELAER; Mj. Winter, ASSOCIATE PROFESSOR SCHLESINGER AND ———.

NOTE.—Whenever, in exceptional cases, the preparation of a student in 2 or 2S justifies it, Qualitative Analysis may be substituted for 3 or 3S.

4. Elementary Organic Chemistry.—Prerequisite: course 3 or 3S. Classroom, 3 hours a week; laboratory, 6 hours a week (subject to change); Mj. Autumn and Spring, ASSISTANT PROFESSOR GLATTFELD.

6. Qualitative Analysis (introductory course).—The lectures deal with the Chemistry of the analytical reactions, and special attention is given to the development and application of the laws of equilibrium and solutions. This course is, in an important sense, one in advanced General Chemistry. Classroom, 2 hours a week; laboratory, 8 or 16 hours a week. Prerequisite: course 3 or 3S. Mj. Summer, ASSOCIATE PROFESSOR WALLEN; Autumn, PROFESSOR STIEGLITZ AND MISS RISING; Winter, MISS RISING; Spring, ———.

7. Qualitative Analysis (continuation of course 6).—Mj. or DM. Summer, ASSOCIATE PROFESSOR WALLEN; Autumn, ASSOCIATE PROFESSOR SCHLESINGER; Winter, ———; and Spring, MISS RISING.

NOTE.—Courses 6, 7, and 10 form a continuous course, which may be begun in any quarter. The aim of courses 6, 7, and 10 will be to train the student to do intelligent analytical work, based on a knowledge of the scientific principles of the subject, and to apply and amplify his knowledge of General and Physical Chemistry.

II. PRIMARILY FOR THE SENIOR COLLEGES

8. Quantitative Analysis (introductory course).—Chiefly laboratory work in gravimetric and volumetric analysis. Laboratory, 8 or 16 hours a week; lecture, 1 hour. Prerequisite: course 7. Medical students will be admitted to the course after having taken course 6. Mj. or DM. Summer, Autumn, and Spring, ASSISTANT PROFESSOR WENDT; Winter, MR. ———.

8M. Quantitative Analysis.—A special course for premedical and medical students giving the elements of gravimetric and volumetric analysis. Prerequisite: course 6. Summer, Autumn, and Spring, ½Mj. ASSISTANT PROFESSOR WENDT; Winter, ½Mj. MR. ———.

9. Quantitative Analysis (continuation of course 8).—Mj. or DM. Laboratory, 10 or 20 hours a week. Mj. Summer, Autumn and Spring, ASSISTANT PROFESSOR WENDT; Winter, MR. ———.

NOTE.—Courses 8 and 9 form a continuous course which may be begun in any quarter.

10. Advanced Qualitative Analysis (continuation of courses 6 and 7).—Open to Senior College students. Prerequisite: course 7. Mj. or DM. Laboratory, 10 or 20 hours a week. Summer, ASSOCIATE PROFESSOR WALLEN; Autumn, ASSOCIATE PROFESSOR SCHLESINGER; Winter, ASSISTANT PROFESSOR TERRY.

11. Theories and Methods of Quantitative Analysis.—½Mj. 2 lectures a week. Prerequisite: Course 9. Autumn, ASSISTANT PROFESSOR WENDT.

12–19. Special Methods in Quantitative Analysis.—

12.	Standard Methods of Water Analysis	½Mj.
13.	Standard Methods of Food Analysis	½Mj. or Mj.
14.	Analysis of Iron, Steels, and Ferro-alloys	½Mj. or Mj.
16.	Preparation and Analysis of Gases	½Mj.
17.	Electrolytic Analysis, Gravimetric	½Mj.
18.	Electrometric Titration	½Mj.
19.	Advanced Rock and Mineral Analysis	Mj.

Laboratory work, 10 hours a week per major. Prerequisite: course 9, but for students in Domestic Science and for medical students, course 8. Summer, Autumn, Spring, ASSISTANT PROFESSOR WENDT; Winter, MR. ———.

15. Organic Elementary Analysis.—½Mj. Summer, ASSISTANT PROFESSOR WENDT; Autumn, Winter, and Spring, ———.

20. Elementary Physical Chemistry.—Mj. 3 hours lectures; 6 hours laboratory work. Prerequisite: Quantitative Analysis. Autumn, PROFESSOR HARKINS.

20S. Elementary Physical Chemistry.—Mj. 3 hours lectures; 6 hours laboratory work. Prerequisite: College Physics and Quantitative Analysis. Summer, PROFESSOR HARKINS.

21. Physical Chemistry (continuation of course 20).—Hours as in 20. Prerequisite: course 20 or its equivalent and Physics 3 and 4. Mj. Winter, PROFESSOR HARKINS.

22. Physical Chemistry (continuation of course 21).—Hours as in 20. Prerequisite: course 21 or its equivalent and the elements of calculus. Spring, PROFESSOR HARKINS.

25. Toxicology.—½Mj. Autumn, PROFESSOR HAINES AND ASSISTANT.

26. Poisons and Their Detection.—A conference and laboratory course. M. Spring, Second Term, PROFESSOR HAINES.

33. General Organic Chemistry.—Fatty and aromatic series. Lectures, 5 hours a week; laboratory work, 10 hours a week. Prerequisite: course 7. DM. First Term, Summer, ASSISTANT PROFESSOR GLATTFELD.

NOTE.—The lectures of courses 33 and 34 may be taken without the laboratory work and without payment of the laboratory fee by students who have had adequate laboratory work in Organic Chemistry.

34. General Organic Chemistry (continuation of course 33).—Prerequisite: course 33 or 4. DM. Second Term, Summer; same hours as course 33. ASSISTANT PROFESSOR GLATTFELD.

NOTE.—The requirement in organic chemistry for premedical students may be met by course 4 or by course 33 and the lectures of 34.

III. PRIMARILY FOR THE GRADUATE SCHOOL

30. Organic Chemistry.—Lectures, 3 hours a week; laboratory, 6 hours a week. Prerequisite: Qualitative Analysis and Elementary Organic Chemistry (course 4 or its equivalent). Mj. Autumn, PROFESSOR STIEGLITZ.

NOTE.—Students who have had adequate laboratory work in Organic Chemistry are admitted to the lectures of courses 30, 31, or 32 without payment of a laboratory fee.

31. Organic Chemistry (continuation of course 30).—Lectures, 3 hours a week; laboratory, 4 hours a week. Mj. Winter, PROFESSOR STIEGLITZ.

32. Organic Chemistry (continuation of course 31).—The Aromatic Series. Lectures, 2 hours a week; laboratory work, 6 hours a week. Prerequisite: course 31 (or course 4 for Medical and Home Economics students). Mj. Spring, PROFESSOR STIEGLITZ.

35. Organic Preparations.—Laboratory work, 10 or 20 hours a week. Prerequisite: courses 7 and 9, and Organic Chemistry. Mj. or DM. ASSISTANT PROFESSOR GLATTFELD; Mj. Autumn, Winter, Spring, ———.

36. Organic Preparations (continuation of course 35).—Prerequisite: course 35 or its equivalent and a reading knowledge of German or French. Mj. or DM. Summer, ASSISTANT PROFESSOR GLATTFELD; Mj. Autumn, Winter, and Spring, ———.

37. Organic Preparations (continuation of course 36).—Mj. or DM. Summer, ASSISTANT PROFESSOR GLATTFELD; Mj. Autumn, Winter, and Spring, ———.

NOTE.—Students who have taken the laboratory work of courses 30, 31 and 32 or of courses 33 and 34 will omit course 35 and go on with course 36.

42. The Carbohydrates.—½Mj. Spring, 1919, ASSISTANT PROFESSOR GLATTFELD.

43. Organic Nitrogen Derivatives.—Uric-acid series, pyridine, quinoneimides, and phenazine compounds; a discussion of the alkaloids, ptomaines, and organic dyestuffs. Prerequisite: course 31. ½Mj. PROFESSOR STIEGLITZ. [Not given in 1919–20.]

44. Physical Chemistry Applied to Organic Problems.—Lectures, 2 hours a week. Prerequisite: courses 31 and 60, 61, or 62. ½Mj. PROFESSOR STIEGLITZ. [Not given in 1919–20.]

45A. Selected Topics of Organic Chemistry.—Reversibility; tautomerism; stereoisomerism; organic dyestuffs; application of the electron theory to organic compounds. Prerequisite: Organic Chemistry. [Not given in 1919–20.]

50. Inorganic Preparations.—Laboratory work, 10 or 20 hours a week; classroom work, 2 hours a week. Prerequisite: course 9. DM. Second Term, Summer and Autumn, PROFESSOR HARKINS; Winter, ASSOCIATE PROFESSOR SCHLESINGER.

51. Inorganic Preparations (continuation of course 50).—Mj. or DM. Prerequisite: course 50 and a reading knowledge of German or French. Same schedule as course 50.

52. Inorganic Preparations (continuation of course 51).—Mj. or DM. Same schedule as course 50.

54. Selected Topics in Inorganic Chemistry.—Discussions of topics in inorganic chemistry selected from such subjects as peroxides and related compounds, complex salts, hydrates, molecular compounds, iso- and heteropoly-acids, Werner's theory, allotrophy, active forms of elements, passive states, etc. Lectures only. ½Mj. Summer, 1920, ASSOCIATE PROFESSOR SCHLESINGER.

55. Advanced General Chemistry.—Discussions bearing chiefly upon the work of courses 50, 51, and 52, and relating to such subjects as temperature measurement, crystal form and habit, isomorphism, solid solution, double salts, thermal analysis, alloys, transition temperatures, etc. This course is intended to supplement the work of the courses in inorganic preparations but can be taken independently. Prerequisite: same as for course 50. Lectures only. ½Mj. Winter, ASSOCIATE PROFESSOR SCHLESINGER.

56. Special Topics in Inorganic Chemistry.—The subjects studied are the valence relations of the elements and the properties of the elements in selected groups of the periodic system. In 1915–16 the helium, the iron, and the rare earth groups were considered. ½Mj. PROFESSOR HARKINS. [Not given in 1919–20.]

56A. Some Recent Developments in Chemistry.—Prerequisite: 1Mj. of Physical Chemistry. Lectures, 5 times a week. M. First Term, Summer, PROFESSOR KRAUS.

57. The Periodic System and the Interrelations of the Elements.—Lectures, ½Mj. PROFESSOR HARKINS. [Not given in 1919–20.]

58. The Constitution of Liquids and Solids: Surface Tension and Colloids.—Lectures. ½Mj. PROFESSOR HARKINS. [Not given in 1918–19.]

59. The Structure of Matter and the Molecular Theory as Applied to Organic Liquids and Solids.—Prerequisite: Physical Chemistry or College Physics, 3 majors. Lectures. ½Mj. PROFESSOR HARKINS. [Not given in 1919–20.]

63. Physicochemical Measurements—Electro-Chemistry. Laboratory work, 10 or 20 hours a week. Prerequisite: course 22 or 20S and Physics 5. Mj. or DM. Summer, First Term, PROFESSOR KRAUS; Second Term, Autumn, Winter, and Spring, PROFESSOR HARKINS.

65. Theories of Solutions I.—½Mj. PROFESSOR HARKINS. [Not given in 1919–20.]

66. Theories of Solutions II.—½Mj. PROFESSOR HARKINS. [Not given in 1919–20.]

67. Selected Topics in Physical Chemistry.—This will be largely a course on the application of physical chemistry to definite problems. Lectures. ½Mj. Winter, ASSOCIATE PROFESSOR SCHLESINGER. [Not given in 1919–20.]

68A, B, C, D. Chemical Thermodynamics.—½Mj. in each Quarter. Prerequisite: Physical Chemistry and Calculus. A in First Term, Summer, and A in Autumn, B in Winter, C in Spring, PROFESSOR HARKINS.

69. The Chemistry of Gas Reactions.—Prerequisite: Physical Chemistry and Calculus. ½Mj. PROFESSOR HARKINS. [Not given in 1919–20.]

75. Radioactivity and the Subatomic Phenomena.—Lectures. Prerequisite: course 20. ½Mj. To be given Summer, 1920, ASSISTANT PROFESSOR WENDT.

76. Laboratory Course in Radioactivity.—To accompany or follow course 75. ½Mj. To be given Summer, 1920. ASSISTANT PROFESSOR WENDT.

79. Photo-Chemistry and Radio-Chemistry.—Prerequisite: course 20. Lectures four hours a week, M. Second Term, Summer. Lectures two hours a week, ½Mj. Spring, ASSISTANT PROFESSOR WENDT.

82. Club Meetings.—Meetings of the Kent Chemical Society will be held twice a month. They may be attended by anyone interested. The subjects for the meetings will be announced at least one week in advance. Summer, Autumn, Winter, and Spring.

85. The Chemistry and Preparation of Medicinal Drugs.—½Mj. Spring, PROFESSOR HAINES.

90–96. Research Work (for the Ph.D. Degree).—These courses will include from 30 to 40 hours a week of laboratory work, under the special direction of some one of the instructors in the Department. It is expected that research work for a Doctor's dissertation will require 4–6 quarters (4–6 DMjs.). Before being admitted to research a candidate must satisfy the instructors of the Department that his previous training has been sufficient.

90. Research in Organic and Physico-organic Chemistry.—Mj. or DMj. Autumn, Winter, and Spring, PROFESSOR STIEGLITZ.

91. Research in Physical Chemistry and Radioactivity.—Mj. or DMj. Summer, Autumn, Winter, and Spring, PROFESSOR HARKINS.

92. Research in Inorganic and Physical Chemistry.—Mj. or DMj. Autumn and Winter, ASSOCIATE PROFESSOR SCHLESINGER.

93. Research in Organic Chemistry.—Mj. or DMj. Autumn, Winter, and Spring, ———.

94. Research in Physico-Organic Chemistry.—Mj. or DMj. Summer, Autumn, and Winter, ASSISTANT PROFESSOR TERRY.

95. Research in Organic Chemistry.—Mj. Summer, Autumn, and Spring, ASSISTANT PROFESSOR GLATTFELD.

96. Research in Radioactivity and Photo-Chemistry.—Mj. or DMj. Summer, Autumn, and Spring, ASSISTANT PROFESSOR WENDT.

97. Independent Research.—Mj. Summer, Autumn, Winter, and Spring.

98A. Masters' Dissertation in Qualitative Analysis.—Mj. Summer, Autumn, and Winter, ASSISTANT PROFESSOR TERRY.

98B. Masters' Dissertation in Organic Chemistry.—Mj. Summer, Autumn, and Spring, ASSISTANT PROFESSOR GLATTFELD.

98C. Masters' Dissertation in Quantitative Analysis.—Mj. Summer, Autumn, and Spring, ASSISTANT PROFESSOR WENDT.

101. Research in the Chemistry of Food.—Mj. Summer, Autumn, and Winter, ASSOCIATE PROFESSOR BLUNT (College of Education).

CHEMISTRY COURSES IN THE DEPARTMENT OF PHYSIOLOGICAL CHEMISTRY

(See the Biological Group *Circular*)

CHEMISTRY COURSES IN THE DEPARTMENT OF GEOLOGY

50. Industrial Geology.—A study of the more important industries in which raw materials of mineral origin are prepared for use. The course includes a brief treatment of the metallurgy of the common metals and a study of the manufacture of coke, cement, clay products, glass, petroleum products, etc. Field trips on Saturdays to plants in and near Chicago are supplemented by detailed reports on each plant. Expenses about $10.00. Classroom work 3 days a week. Prerequisite: Geology 2, 3, 5, or 12 and a working knowledge of Chemistry. Mj. ASSISTANT PROFESSOR BROKAW. [Not given in 1919–20.]

51. Petroleum and Coal.—An advanced course on petroleum and coal. The course includes a critical study of (1) the modern theories of origin, (2) the location, stratigraphy, and structure of the important fields of the world, (3) the methods of prospecting and exploiting the deposits, and (4) technology of oil and coal. Prerequisite: Geology 16. Desirable antecedent, Organic Chemistry. Mj. ASSISTANT PROFESSOR BROKAW. [Not given in 1919–20.]

52. Ore Deposits.—A discussion of the principles of ore deposition; the nature, distribution, and genesis of metalliferous ore deposits in the United States; a study of the relations of ore deposits to geological structure and of the changes which ore deposits undergo through processes conditioned by factors related to depth. The course includes laboratory work illustrating the uses of mine maps and the compilation of geologic cross-sections through mines. Prerequisite: Geology 12, 16, and 30, Chemistry 6, Mathematics 3. Desirable antecedents: Mathematics 5, Mechanical Drawing, and Geography 12. Mj. Winter, ASSISTANT PROFESSOR BROKAW.

53. Chemistry of Ore Deposits.—The course will include (1) a study of physical and chemical laws applied to geological problems, with special reference to the phenomena involved in the formation of ore deposits; (2) studies in paragenesis and the interpretation of paragenetic groups of minerals; (3) the study and critical interpretation of geologic and mining reports dealing with the origin of ore bodies. Prerequisite: Geology 40. Mj. Spring, ASSISTANT PROFESSOR BROKAW. [May not be given in 1919–20.]

54. Field Work in Mining and Mining Geology.—Students in Mining Geology are advised to spend some of their summers in mining camps where they may find employment as miners, mine samplers, assayers, draughtsmen, surveyors, etc. For the sake of experience it is desirable that they serve in as many different capacities as practicable. In many mining camps opportunity is offered for a study of General Geology, ore deposits, mining machinery, metallurgical works, etc. Frequent communication with the instructor is required, and when the work and reports are sufficiently thorough, credit will be given. Prerequisite: course 40. Summer, ASSISTANT PROFESSOR BROKAW.

CHEMISTRY COURSES IN THE DEPARTMENT OF HOME ECONOMICS

36. Chemistry of Food.—Study of the chemistry of fats, carbohydrates, proteins, as food constituents, with special emphasis upon the composition and nutritive value of such foods as meat, flour, milk, butter, etc. The laboratory is partly qualitative and partly quantitative. Prerequisite: Organic Chemistry. Laboratory fee, $3.00. Mj. Summer, Autumn, and Winter, ASSISTANT PROFESSOR BLUNT AND MISS MCKEE.

37. Chemistry of Food (continued).—A continuation of the work in course 36. The subject-matter may be adapted to the special needs of the students. Lecture and laboratory. For graduate or Senior College students. Prerequisite: Home Economics 36 or its equivalent. Laboratory fee, $3.00. Mj. Autumn, ASSISTANT PROFESSOR BLUNT AND MISS MCKEE.

38A. Nutrition.—A study of the processes of digestion and metabolism, and the nutritive requirements of the body, giving a scientific basis for the work in dietaries. The laboratory work consists chiefly of experiments on digestion and of qualitative and quantitative urine analysis in connection with special diets. Students may follow this course by either 39A or 38B, or both. Prerequisite: Home Economics 36. Laboratory fee, $1.50. M. Summer, First and Second Terms; Winter, First Term, ASSISTANT PROFESSOR BLUNT AND MISS ELIZABETH W. MILLER.

38B. Nutrition (continued).—A continuation of 38A. The course may include some study of pathological conditions in metabolism and a feeding or metabolism experiment. Laboratory fee, $1.50. M. Summer, Second Term, and Winter, Second Term, ASSISTANT PROFESSOR BLUNT.

39A. Dietaries.—A study of the food requirements of individuals as modified by age, sex, activity, etc., with special consideration given to the food of school children and institutional groups. The theory of infant feeding is included. Prerequisite: Home Economics 3 or 5 and 38A. Laboratory fee, $2.50. M. Summer and Winter, Second Term, 10:30–12:30, MISS ELIZABETH W. MILLER.

40. Readings in Nutrition.—Reading and discussion of some of the recent work on normal and abnormal nutrition. Prerequisite: Home Economics 38A and 39A or their equivalent. The consent of the instructor must be obtained before registering. M. Summer, Second Term; ½Mj. Winter, ASSISTANT PROFESSOR BLUNT AND MISS ELIZABETH W. MILLER.

DOCTORS OF PHILOSOPHY OF THE UNIVERSITY OF CHICAGO

MATHEMATICS

1896 Leonard Eugene Dickson, Professor of Mathematics, University of Chicago.
The Analytic Representation of Substitutions on a Power of a Prime Number of Letters with a Discussion of the Linear Group.

John Irwin Hutchinson, Professor of Mathematics, Cornell University, Ithaca, N.Y.
On the Reduction of Hyperelliptic Functions ($p=2$) to Elliptic Functions by a Transformation of the Second Degree.

1898 Herbert Ellsworth Slaught, Professor of Mathematics, University of Chicago.
The Cross-Ratio Group of 120 Quadratic Cremona Transformations of the Plane.

1899 John Anthony Miller, Professor of Mathematics and Astronomy, Swarthmore College, Swarthmore, Pa.
Concerning Certain Elliptic Modular Functions of Square Rank.

1900 Gilbert Ames Bliss, Professor of Mathematics, University of Chicago.
The Geodesic Lines on the Anchor Ring.

George Lincoln Brown, Professor of Mathematics, South Dakota Agricultural College, Brookings, S.D.
A Ternary Linear Substitution Group of Order 3·360.

William Gillespie, Professor of Mathematics, Princeton University, Princeton, N.J.
On the Reduction of Hyperelliptic Integrals ($p=3$) to Elliptic Integrals by Transformation of the Second and Third Degree.

Derrick Norman Lehmer, Associate Professor of Mathematics, University of California, Berkeley, Cal.
Asymptotic Evaluation of Totient Sums.

John Hector McDonald, Assistant Professor of Mathematics, University of California, Berkeley, Cal.
On the System of a Binary Cubic and Quadratic and the Reduction of Hyperelliptic Integrals of Genus Two to Elliptic Integrals by a Transformation of the Fourth Order.

Ernest Brown Skinner, Assistant Professor of Mathematics, University of Wisconsin, Madison, Wis.
Ternary Monomial Substitution Groups of Finite Order with Determinant ± 1.

1901 William Findlay, Professor of Mathematics, McMaster University, Toronto, Ont.
The Sylow Subgroups of the Symmetric Group.

Thomas Milton Putnam, Associate Professor of Mathematics and Dean of the Lower Division, University of California, Berkeley, Cal.
The Quaternary Linear Homogeneous Group and the Ternary Linear Fractional Group.

1903 Oswald Veblen, Professor of Mathematics, Princeton University, Princeton, N.J.; Major, Ordnance Department.
A System of Axioms for Geometry.

1904 William Henry Bussey, Associate Professor and Chairman of the Department of Mathematics, University of Minnesota, Minneappolis, Minn.
Generational Relations for the Abstract Group Simply Isomorphic with the Group LF(2; p^n).

Herbert Edwin Jordan, Assistant Professor of Mathematics, University of Kansas, Lawrence, Kan.
Group Characters of Various Linear Groups.

Arthur Whipple Smith, Associate Professor of Mathematics, Colgate University, Hamilton, N.Y.
Symbolic Treatment of Differential Geometry.

1905 Thomas Emory McKinney, Professor of Mathematics and Astronomy, University of South Dakota, Vermilion, S.D.
Concerning a Certain Type of Continued Fractions Depending on a Variable Parameter.

Robert Lee Moore, Assistant Professor of Mathematics, University of Pennsylvania, Philadelphia, Pa.
Sets of Metrical Hypotheses for Geometry.

1906 William Raymond Longley, Assistant Professor of Mathematics, Yale University, New Haven, Conn.
A Class of Periodic Orbits of an Infinitesimal Body Subject to the Attraction of n Finite Bodies.

Arthur Ranum, Assistant Professor of Mathematics, Cornell University, Ithaca, N.Y.
The Group of Classes of Congruent Matrices with Application to the Group of Isomorphisms of Any Abelian Group.

Anthony Lispenard Underhill, Assistant Professor of Mathematics, University of Minnesota, Minneapolis, Minn.; Captain, Coast Artillery, in France.
Invariants under Point Transformations in the Calculus of Variations.

Buzz M. Walker, Professor of Mathematics and Director of School of Engineering, Mississippi Agricultural and Mechanical College, Agricultural College, Miss.
On the Resolution of Higher Singularities of Algebraic Curves into Ordinary Double Points.

1907 George David Birkhoff, Assistant Professor of Mathematics, Harvard University, Cambridge, Mass.
Asymptotic Properties of Certain Ordinary Differential Equations, with Applications to Boundary Value and Expansion Problems.

Robert Lacey Börger, Professor of Mathematics, Ohio University, Athens, Ohio.
On the Determination of Ternary Linear Groups in the Galois Field of Order p^2.

Louis Ingold, Assistant Professor of Mathematics, University of Missouri, Columbia, Mo.
Vector Interpretation of Symbolic Parameters.

Nels Johann Lennes, Professor of Mathematics, University of Montana, Missoula, Mont.
Curves in Non-metrical Analysis Situs with an Application in the Calculus of Variations.

Frederick William Owens, Assistant Professor of Mathematics, Cornell University, Ithaca, N.Y.
The Introduction of Ideal Elements and Construction of Projective n-space in Terms of a Planar System of Points.

1907 Norman Richard Wilson, Professor of Mathematics, University of Manitoba, Winnipeg, Canada; on leave of absence on military service, Lieutenant, Artillery Corps, B.E.F.
Isoperimetrical Problems Which Are Reducible to Non-isoperimetrical Problems.

1908 Mary Emily Sinclair, Associate Professor of Mathematics, Oberlin, College, Oberlin, Ohio.
On a Compound Discontinuous Solution Connected with the Surface of Revolution of Minimum Area.

1909 Thomas Buck, Assistant Professor of Mathematics, University of California, Berkeley, Cal.; First Lieutenant, Ordnance Department.
Oscillating Satellites near the Lagrangian Equilateral Triangular Points.

Arnold Dresden, Assistant Professor of Mathematics, University of Wisconsin, Madison, Wis.; American Red Cross, Paris, France.
The Second Derivatives of the Extremal-Integral.

Harris Franklin MacNeish, Instructor in Mathematics, DeWitt Clinton High School, New York, N.Y.
Linear Polars of the k-hedron in n-space.

1910 Richard Philip Baker, Assistant Professor of Mathematics, State University of Iowa, Iowa City, Iowa.
The Problem of the Angle-Bisectors.

William Hunt Bates, Associate Professor of Mathematics, Purdue University, Lafayette, Ind.
An Application of Symbolic Methods to the Treatment of Mean Curvatures in Hyper-Space.

Theophil Henry Hildebrandt, Assistant Professor of Mathematics, University of Michigan, Ann Arbor, Mich.; Instructor, F.A.C.O.T.S., Camp Zachary Taylor.
A Contribution to the Foundations of Fréchet's Calcul Fonctionnel.

Egbert J. Miles, Assistant Professor of Mathematics, Yale University, New Haven, Conn.
The Absolute Minimum of a Definite Integral in a Special Field.

Anna Johnson Pell, Associate Professor of Mathematics, Bryn Mawr College, Bryn Mawr, Pa.
I. Biorthogonal Systems of Functions. II. Application to the Theory of Integral Equations.

Arthur Dunn Pitcher, Professor of Mathematics, Western Reserve University, Cleveland, Ohio.
The Interrelation of Eight Fundamental Properties of Classes of Functions.

Marion Ballantyne White, Professor of Mathematics, Carleton College, Northfield, Minn.
The Dependence of the Focal Point on Curvature in Space Problems of the Calculus of Variations.

1911 Lloyd Lyne Dines, Professor of Mathematics, University of Saskatchewan, Saskatoon, Canada.
The Highest Common Factor of a System of Polynomials, with an Application to Implicit Functions.

Theodore Lindquist, Professor of Mathematics, State Normal School, Emporia, Kan.
Mathematics for Freshman Students of Engineering.

Ralph Eugene Root, Professor of Mathematics, U.S. Naval Academy, Annapolis, Md.
Interated Limits in General Analysis.

1911 ALBERT HARRIS WILSON, Associate Professor of Mathematics, Haverford College, Haverford, Pa.
The Canonical Types of Nets of Quadratic Forms in the Galois Field of Order p^n.

1912 EDWARD WILSON CHITTENDEN, Assistant Professor of Mathematics, State University of Iowa, Iowa City, Iowa.
Infinite Developments and the Composition Property $(K_{12}B_1)_*$ in General Analysis.

CHARLES ALBERT FISCHER, Instructor in Mathematics, Columbia University, New York, N.Y.
Some Contributions to the Theory of Functions of Lines.

CHARLES THOMPSON SULLIVAN, Assistant Professor of Mathematics, McGill University, Montreal, Canada.
Properties of Surfaces Whose Asymptotic Lines Belong to Linear Complexes.

1913 WILLIAM CHARLES KRATHWOHL, Assistant Professor of Mathematics Armour Institute of Technology, Chicago, Ill.
Modular Invariants of Two Pairs of Cogredient Variables.

WILSON LEE MISER, Assistant Professor of Mathematics, University of Arkansas, Fayetteville, Ark.
On Linear Homogeneous Differential Equations with Elliptic Function Coefficients.

FRANK MARION MORRISON, Greenville, Ohio; Sometime Associate Professor of Mathematics, University of Washington, Seattle, Wash.
On the Relation between Some Important Notions of Projective and Metrical Differential Geometry.

ELTON JAMES MOULTON, Assistant Professor of Mathematics, Northwestern University, Evanston, Ill.
On Figures of Equilibrium of a Rotating Heterogeneous Fluid Body.

†MILDRED LEONORA SANDERSON. Late Instructor in Mathematics, University of Wisconsin.
Formal Modular Invariants with an Application to Binary Modular Covariants.

1914 MYER GRUPP GABA, Assistant Professor of Mathematics, University of Nebraska, Lincoln, Neb.
A Set of Postulates for General Projective Geometry of n Dimensions.

HAROLD REYNOLDS KINGSTON, Instructor in Mathematics, University of Manitoba, Winnipeg, Canada.
Metric Properties of Nets of Plane Curves.

WILLIAM VERNON LOVITT, Associate Professor of Mathematics, Colorado College, Colorado Springs, Colo.
A Type of Singular Points for a Transformation of Three Variables.

FORBES BAGLEY WILEY, Professor of Mathematics, Denison University, Granville, Ohio.
Proof of the Finiteness of Modular Covariants of a System of Binary Form of Cogredient Points.

1915 ALLEN FULLER CARPENTER, Assistant Professor of Mathematics, University of Washington, Seattle, Wash.
Ruled Surfaces Whose Flecnode Curves Have Plane Branches.

CHARLES ROSS DINES, Federal Reserve Bank, Chicago, Ill.
Functions of Positive Type and Selected Topics in General Analysis.

† Deceased, October 15, 1914.

1915 Jasper Ole Hassler, Instructor in Mathematics, Crane Junior College, Chicago, Ill.
Plane Nets Periodic of Period Three under the Laplace Transformation.

Olive Clio Hazlett, Instructor in Mathematics, Mount Holyoke College, South Hadley, Mass.
On the Classification and Invariantive Characterizations of Nilpotent Algebras.

Archibald Henderson, Professor of Mathematics, University of North Carolina, Chapel Hill, N.C.
The Twenty-seven Lines upon the Cubic Surface.

Alfred Lewis Nelson, Instructor in Mathematics, University of Michigan, Ann Arbor, Mich.
Plane Nets with Equal Laplace-Darboux Invariants.

Vincent Collins Poor, Instructor in Mathematics, University of Michigan, Ann Arbor, Mich.
A Certain Type of Exact Solution of the Equations of Motion of a Viscous Liquid.

Samuel Watson Reaves, Professor of Mathematics, University of Oklahoma, Norman, Okla.
Metric Properties of Flecnodes on Ruled Surfaces.

Mary Evelyn Wells, Instructor in Mathematics, Vassar College, Poughkeepsie, N.Y.
The Determination of All Inequalities of Certain Types in General Linear Integral Equation Theory.

Chester Henry Yeaton, Instructor in Mathematics, University of Minnesota; Aërological Service, Signal Corps, Richmond, Me.
Surfaces Characterized by Certain Properties of Their Directrix Congruences.

1916 Elmer Daniel Grant, Assistant Professor of Mathematics, Michigan School of Mines, Houghton, Mich.
The Motion of a Flexible Cable in a Vertical Plane.

Arthur McCracken Harding, Professor of Mathematics, University of Arkansas, Fayetteville, Ark.
On Certain Loci Projectively Connected with a Given Plane Curve.

William Leroy Hart, Major, Coast Artillery, A.E.F.
Differential Equations and Implicit Functions in Infinitely Many Variables.

Gillie Aldah Larew, Adjunct Professor of Mathematics, Randolph–Macon Woman's College, Lynchburg, Va.
Necessary Conditions for the Problem of Mayer in the Calculus of Variations.

Arthur Shepard Merrill, Assistant Professor of Mathematics, University of Montana, Missoula, Mont.; Ships' Calculator, U.S. Navy Reserve Forces.
An Isoperimetric Problem with Variable End-Points.

Arthur Richard Schweitzer, Chicago, Ill.
Les Idées directrices de la logique génétique des mathématiques.

David Melville Smith, Assistant Professor of Mathematics, Georgia School of Technology, Atlanta, Ga.
Jacobi's Condition for the Problem of Lagrange in the Calculus of Variations.

Pauline Sperry, Instructor in Mathematics, University of California, Berkeley, Cal.
Properties of a Certain Projectively Defined Two Parameter Family of Curves on a General Surface.

1917 Jacob Millison Kinney, Instructor in Mathematics, Hyde Park High School, Chicago.
The General Theory of Congruences without Any Preliminary Integration.

Kenneth Worcester Lamson, Instructor in Mathematics, Columbia University, New York, N.Y.
A General Implicit Function Theorem, with an Application to Problems of Relative Minimum.

Flora Elizabeth Le Stourgeon, Instructor in Mathematics, Mount Holyoke College, South Hadley, Mass.

†James Elijah McAtee, Late Instructor in Mathematics, University of Illinois.
Modular Invariants of a Quadratic Form for a Prime Power Modulus.

Thomas McNider Simpson, Jr., Assistant Professor of Mathematics, University of Texas, Austin, Tex.; American Y.M.C.A., France.
Relation between the Metric and Projective Theories of Space Curves.

William Pinkerton Ott, Instructor in Mathematics, University of Nashville, Nashville, Tenn.
The General Problem of the Type of the Brachistochrone with Variable End-Points.

Levi Stephen Shively, Professor of Mathematics and Acting President, Mount Morris College, Mount Morris, Ill.
A New Basis for the Metric Theory of Congruences.

1918 Ernest Preston Lane, Instructor in Mathematics, Rice Institute, Houston, Tex.
Conjugate Systems with Indeterminate Axis Curves.

Israel Albert Barnett, Instructor in Mathematics, Washington University, St. Louis, Mo.
Differential Equations with a Continuous Infinitude of Variables.

Webster Godman Simon, Instructor in Mathematics, Western Reserve University, Cleveland, Ohio.
On the Solution of Certain Types of Linear Differential Equations in Infinitely Many Variables.

George Hoffman Cresse, Instructor in Mathematics, University of Michigan.
On the Class Numbers of Binary Quadratic Forms.

MATHEMATICAL ASTRONOMY

1900 Forest Ray Moulton, Professor of Astronomy, University of Chicago.
Periodic Oscillating Satellites.

1903 William Albert Hamilton, Professor of Astronomy, Beloit College, Beloit, Wis.
The True Radii of Convergence for Expansions as Power Series in the Time, in the Case of Parabolic Motion.

1904 Arthur Constant Lunn, Associate Professor of Applied Mathematics, University of Chicago.
The Differential Equations of Dynamics.

1905 Delonzo Tate Wilson, Assistant Professor of Mathematics, Case School of Applied Science, Cleveland, Ohio.
Work on Minor Planets.

† Deceased, December 2, 1918.

1906 Frank Loxley Griffin, Professor of Mathematics, Reed College, Portland, Ore.
Certain Periodic Orbits of k Finite Bodies Revolving about a Relatively Large Central Mass.

1908 William Duncan MacMillan, Assistant Professor of Astronomy, University of Chicago.
Periodic Orbits about an Oblate Spheroid.

1909 Herbert Earle Buchanan, Professor of Mathematics, University of Tennessee, Knoxville, Tenn.
Periodic Oscillations of Three Finite Masses about the Langrangian Circular Solutions.

1911 Daniel Buchanan, Assistant Professor of Mathematics, Queen's University, Kingston, Ont.
A Class of Periodic Solutions of the Problem of Three Bodies, Two of Equal Mass, the Third Moving on a Straight Line.

1913 Lloyd Arthur Heber Warren, Assistant Professor of Mathematics, University of Manitoba, Winnipeg, Canada.
A Class of Asymptotic Orbits in the Problem of Three Bodies.

1915 John William Campbell, Lecturer in Mathematics, Wesley College, Winnipeg, Canada.
Periodic Solution of the Problem of Three Bodies in Three Dimensions.

Louis Allen Hopkins, Instructor in Mathematics, University of Michigan, Ann Arbor, Mich.
On the Theory of the Motion of the Small Planets with a Periodic Orbit for the Hilda Type.

PRACTICAL ASTRONOMY AND ASTROPHYSICS

1913 Curvin Henry Gingrich, Assistant Professor of Astronomy, Carleton College, Northfield, Minn.
A Determination of the Photographic Magnitudes of Comparison Stars in Certain Hagen Fields.

Oliver Justin Lee, Instructor in Practical Astronomy, Yerkes Observatory, Williams Bay, Wis.
The Spectroscopic System 9 Camelopardalis.

1914 Frank Craig Jordan, Assistant Professor of Astronomy, University of Pittsburgh.
The Color-Changes of Certain Variable Stars of Short Periods.

1915 Harlan True Stetson, Instructor, Students' Astronomical Laboratory, Harvard University, Cambridge, Mass.
On the Apparatus and on Methods for Thermoelectric Measurements in Photographic Photometry, with Application to the Determination of Magnitude, Spectral Intensities, and the Light Curves of Variable Stars.

1917 Edwin Powell Hubble, Major, U.S.A. in France.
Photographic Investigations of Faint Nebulae.

PHYSICS

1897 Gordon Ferry Hull, Professor of Physics, Dartmouth College; Major in Ordnance, U.S.A.
On the Use of the Interferometer in the Study of Electric Waves.

Isabel Stone, Principal of American School for Girls, Rome, Italy.
On the Electrical Resistance of Thin Films.

1898 Edwin Sheldon Johonnott, Associate Professor of Physics, Rose Polytechnic Institution.
Thickness of the Black Spot in Liquid Films.

1899 Henry Gordon Gale, Professor of Physics, University of Chicago; Major in Signal Corps, U.S.A.
On the Relation between Density and Index of Refraction of Air.

1900 Robert Francis Earhart, Professor of Physics, Ohio State University.
The Sparkling Potentials between Plates at Small Distances.

1901 Fritz Reichmann, Practical Physicist, Troy, N.Y.
The Capacities of Air Condensers for Very Small Distances between the Plates.

1902 Frank Baldwin Jewett, Chief Engineer, Western Electric Co., New York, N.Y.; Lieutenant Colonel, Signal Corps, U.S.A.
A New Method of Determining the Vapor-Density of Metallic Vapors.

1904 Thomas Eaton Doubt, Associate Professor of Physics, Armour Institute of Technology, Chicago, Ill.
The Effect of Intensity upon the Velocity of Light.

Fannie Cornelia Frisbee (Mrs. Frank B. Jewett), New York, N.Y.
The Effects of Pressure on Magnetic Induction.

1904 Thomas Carlyle Hebb, Professor of Physics, University of British Columbia, Vancouver, Canada.
The Velocity of Sound.

1905 Frederic Lendhall Bishop, Professor of Physics, University of Pittsburgh, Pittsburgh, Pa.
The Thermal Conductivity of Lead.

Glenn Moody Hobbs, Secretary of the American School of Correspondence, Chicago, Ill.
The Relation between P.D. and Spark-Length for Small Values of the Latter.

Carleton John Lynde, Professor of Physics, MacDonald College, Quebec, Canada.
The Effect of Pressure on Surface Tension.

1906 William Richard Blair, Head of Aërological Service of the Weather Bureau, Washington, D.C.; Major, A.E.F.
The Change of Phase Due to the Passage of Electric Waves through Thin Films.

Lawrence Emery Gurney, Professor of Physics, University of the Philippines, Manila, P.I.
The Viscosity of Water at Low Rate of Shear.

1907 Oliver Charles Clifford, Associate Professor of Electrical Engineering, Armour Institute of Technology, Chicago, Ill.
Susceptibility of Copper and Tin and Their Alloys.

George Winchester, Professor of Physics, Washington and Jefferson College, Washington, Pa.; Lieutenant, A.E.F.
Discharge of Electricity from Metals under the Influence of Ultra-Violet Light.

1909 William Ross Ham, Professor of Physics, Pennsylvania State College, State College, Pa. Captain in Ordnance, U.S.A.
The Polarization of Primary X-Rays.

Charles Albert Proctor, Professor of Physics, Dartmouth College, Hanover, N.H. Captain, U.S.A.

The Variation of $\frac{e}{m}$ with Speed in the Case of Cathode Rays.

1909 Newland Farnsworth Smith, Professor of Physics, Central College, Danville, Ky.
Effect of Tension on Thermal and Electrical Conductivity.

1910 Louis Begeman, Professor of Physics, Iowa State Teachers' College.
The Determination of "E" by the Cloud Method.

J. Harry Clo, Professor of Physics, Tulane University, New Orleans, La.
The Effect of Temperature upon the Ionization of Gas.

Ansel Alphonso Knowlton, Professor of Physics, Reed College, Portland, Ore.
Preparation and Testing of Heusler Alloys.

John Mathias Kuehne, Associate Professor of Physics, University of Texas, Austin, Tex.
The Electrostatic Effect of a Changing Magnetic Field.

James Remus Wright, Associate Professor of Physics, University of the Philippines, Manila, P.I.
Photo-electric Effects of Aluminum as a Function of the Wave-Length of the Incident Light.

1911 Harold De Forest Arnold, Head of Research Laboratory, Bell Telephone Company, New York; Captain, U.S.A.
Limitations Imposed by Slip and Inertia Terms upon Stokes Law for the Motion of Spheres through Liquids.

1911 †Edwin Sherwood Bishop, Instructor in Physics, University High School, University of Chicago.
A Determination of the Minimum Ionizing Kinetic Energy of an Electron in a Gas.

Harvey Fletcher, Research Laboratory, Bell Telephone Co., New York, N.Y.
A Verification of the Theory of Brownian Movements and a Direct Determination of the Value of Ne for Gaseous Ionization.

Harvey Brace Lemon, Assistant Professor of Physics, University of Chicago; Captain in Ordnance, U.S.A.
The Influence of Temperature upon the Intensities of the Lines of the Hydrogen Spectrum.

Howard Wilson Moody, Professor of Physics, Mississippi Agricultural College, Agricultural College, Miss.
A Determination of the Ratio of the Specific Heats and the Specific Heat at Constant Pressure of Air and Carbon Dioxide.

1913 Lachlan Gilchrist, Instructor in Physics, University of Toronto; Captain, British Army.
An Absolute Determination of the Viscosity of Air.

Edward James Moore, Associate Professor of Physics, Oberlin College, Oberlin, Ohio.
Reaction Effects Produced by the Discharge of Electricity from Points in Gases and the Bearing of These Effects on the Theory of the Small Ion.

1914 Albert Edward Hennings, Assistant Professor of Physics, University of Saskatchewan, Saskatoon, Canada.
A Study of the Contact Potentials and Photo-electric Properties of Metals *in Vacuo*.

Verne Frank Swaim, Assistant Professor of Physics, Bradley Polytechnic Institute, Peoria, Ill.
The Pressure-Shift of Lines in the Spectrum of Zinc.

† Deceased.

1915 William Henry Kadesch, Instructor in Physics, U.S. Naval Academy, Annapolis, Md.
The Energy of Photo-Electrons from Sodium and Potassium as a Function of the Frequency of the Incident Light.

John Yui-Bong Lee, 520 Alin Street, Oakland, Cal.
The Determination of "E" by the Millikan Method Using Solid Spheres.

Isaiah March Rapp, Professor of Physics, University of Oklahoma, Norman, Okla.
The Flow of Air through Capillary Tubes.

Oscar William Silvey, Professor of Physics, Texas Agricultural and Mechanical College, College Station, Tex.
A Comparison of the Fall of a Droplet in a Liquid and in a Gas.

1916 Arthur Jeffrey Dempster, Instructor in Physics, University of Chicago; Lieutenant, A.E.F.
The Properties of Slow Canal Rays.

Ertle Leslie Harrington, The Westinghouse Co., Research Laboratory, N.Y.
A Redetermination of the Absolute Value of the Coefficient of Viscosity of Air.

Yoshio Ishida, Assistant in Physics, University of Chicago.
The Kinetic Theory of Rigid Molecules.

Leonard B. Loeb, The Bureau of Standards, Washington, D.C., Lieutenant, A.E.F.
Mobility of Gaseous Ions in High Electric Fields.

1916 Carl Danforth Miller, The Westinghouse Research Laboratory, Pittsburgh, Pa.; Lieutenant in Ordnance, U.S.A.
Absorption Coefficients of Soft X-Rays.

Benjamin Estill Shackelford, The Westinghouse Company, New York, N.Y.
Temperature and Blackening Effects in Helical Tungsten Filaments.

William Henry Souder, Physicist at Bureau of Standards, Washington, D.C.
The Normal Photo-electric Effect of Lithium, Sodium, and Potassium as a Function of Wave-Lengths and Incidental Energy.

Walter Ticknor Whitney, Claremont, Cal.
The Pole Effect in a Calcium Arc.

1917 Karl Kelchner Darrow, Bell Telephone Co., New York, N.Y.
Preliminary Report on a New Method for Determining the Velocity of Sound in Gases.

Victor Hugo Gottschalk.
The Nature of the Process of Ionization by Alpha Rays.

Leopold Joseph Lassalle, Professor of Physics, Pennsylvania State College, State College, Pa.
The Law of Fall of a Sphere through Carbon Dioxide and an Exact Determination of the Viscosity of That Gas.

Margaret Calderwood Shields, Department of Physics, Mount Holyoke College, South Hadley, Mass.
A Determination of the Ratio of the Specific Heats of Hydrogen at 18 Degrees and −190 Degrees.

1919 Charles Frederick Hagenow.
Thermionic and Photoelectric Phenomena at the Lowest Attainable Pressures.

1919 Henry W. Nichols.
Theory of Variable Dynamical-Electrical Systems.

Leland J. Stacey.
A Determination by the Constant-Deflection Method of the Value of the Coefficient of Slip for Rough and for Smooth Surfaces in Air.

CHEMISTRY

1894 Adolph Bernhard, State Normal School, La Crosse, Wis.
Ueber die Einführung von Acylen in den Benzoylessigaether.

Warren Rufus Smith, Professor and Head of the Department of Chemistry, Lewis Institute, Chicago, Ill.
On the Addition Products of the Aromatic Isocyanides.

1896 Bernard Conrad Hesse, Consulting Chemist, General Chemical Co., New York City.
On Malonic Nitrile and Some of Its Derivatives.

Samuel Ellis Swartz, Professor of Chemistry and Physics, Fairmount College, Wichita, Kan.
The Action of Sodium Ethylate on Amide Bromides.

1897 James Bert Garner, Professor and Head of Department of Chemical Engineering, University of Pittsburgh, and Director of Research, Hope Natural Gas Co., Pittsburgh, Pa.
Condensations with Benzoin by Means of Sodium Ethylate.

Lauder William Jones, Professor and Dean of the College of Chemistry, University of Minnesota, Minneapolis, Minn.; Chief of the Offense Chemical Research Section, Chemical Warfare Service, Washington, D.C.
On Salts of Nitroparaffine and Acylated Derivatives of Hydroxylamine.

1898 Frank Burnett Dains, Professor of Chemistry, University of Kansas, Lawrence, Kan.
On the Isourea Ethers and Other Derivatives of Ureas.

Otto Folin, Hamilton Kuhn Professor of Biological Chemistry, Harvard University, Cambridge, Mass.
On Urethanes Medical School, Boston, Mass.

Elizabeth Jeffreys, Professor of Chemistry, Pritchett College, Glasgow, Mo.
On Undecylamine and Pentadecylamine and the Preparation of the Higher Amines of the Aliphatic Series.

Herbert Newby McCoy, Carnotite Reduction Co., Lindsay Light Co., Chicago, Ill.
On the Hydrochlorides of Carbo-phenylimido Derivatives.

1899 John Charles Hessler, Professor of Chemistry and Dean of James Millikin University, Decatur, Ill.
On Alkyl Malonic Nitriles and Their Derivatives.

William McPherson, Professor and Head of the Department of Chemistry and Dean of the Graduate School, Ohio State University, Columbus, Ohio; Lieutenant Colonel, Chemical Warfare Service, U.S.A., Edgewood Arsenal, Edgewood, Md.
On the Nature of the Oxyazo Compounds.

James Harvey Ransom, Professor and Chairman of the Department of Chemistry, Vanderbilt University, Nashville, Tenn.
On the Molecular Rearrangement of o-Aminophenyl Ethyl Carbonate to o-Oxyphenylurethane.

1900 Henry Chalmers Biddle, Berkeley, Cal.
Ueber Derivate des Isuretins, der Formhydroxamsäure und ihre Beziehungen zur Knallsäure.

1901 Ralph Harper McKee, Director of Research Laboratory, Tennessee Copper Co., Ridgewood, N.J., and Professor of Chemical Engineering, Columbia University, New York, N.Y.
On the Oxygen Ethers of the Ureas: Methyl- and Ethylisourea.

1902 Solomon Farley Acree, Research Chemist, National Wood Chemical Association, Syracuse, N.Y.
On Sodium Phenyl and the Action of Sodium on Ketones.

Wallace Appleton Beatty, New York, N.Y.
The Action of Carbon Monoxide on Sodium Alcoholates Alone and in the Presence of Salts of Fatty Acids.

Eugene Paul Schoch, Professor and Chairman of the School of Chemistry and Chairman of the School of Chemical Engineering, University of Texas, Austin, Tex.
The Red and the Yellow Mercuric Oxides and the Mercuric Oxychlorides.

Edwin Emery Slosson, Literary Editor of *The Independent*, New York City.
On Acylhalogenamine Derivatives and the Beckmann Rearrangement.

1903 Henry Tabor Upson, President and Treasurer, Pease Oil Co., Buffalo, N.Y.
The Molecular Rearrangement of Aminophenylalkyl Carbonates.

1904 Maxwell Adams, Professor of Chemistry, University of Nevada, Reno, Nev.
On Some Hydroxylamine Compounds.

Raymond Foss Bacon, Director of the Mellon Institute of Industrial Research, University of Pittsburgh, Pittsburgh, Pa.; Colonel, Chief of the Technical Division, Chemical Warfare Service, U.S.A., American Expeditionary Forces, France.
On the Reactions of Sodium Benzhydrol.

William McAfee Bruce, Manager, Eastern Arkansas Demonstration Farm, Blackton, Ark.
On the Oxygen Ethers of Urea.

Nellie Esther Goldthwaite, Kobe, Japan.
On Substituted Benzhydrol Derivatives and Bromcyanacetic Ether.

Oswin W. Willcox, Chief Chemist and Superintendent, Aetna Explosives Co., Mount Union, Pa.
On the Reactions of Ethyl Chlorsulphonate.

1905 William Lloyd Evans, Professor of Chemistry, Ohio State University, Columbus, Ohio; Major, Chemical Warfare Service, in charge Chemical Laboratory, Edgewood Arsenal, Edgewood, Md.
On the Behavior of Benzoyl Carbinol toward Alkalies and Oxidizing Agents.

William McCracken, Professor of Natural Sciences, State Normal School, Kalamazoo, Mich.
Studies in Catalysis. V. The Catalysis of Imidoesters.

Hermann I. Schlesinger, Associate Professor of Chemistry, University of Chicago.
Studies in Catalysis. VI. The Catalysis of Imidoesters.

1906 Roy Hutchinson Brownlee, Director, American Carbo-Hydrogen Products Co., Pittsburgh, Pa.
On Precipitated Sulphur.

1906 Charles M. Carson, Professor and Head of the Department of Chemistry, Houghton School of Mines, Houghton, Mich.
On Amorphous Sulphur: Further Study of the Two Forms of Liquid Sulphur as Dynamic Isomers.

Henry Max Goettsch, Assistant Professor of Technical Chemistry, University of Cincinnati, Cincinnati, Ohio.
The Absorption Coefficients of Uranium Compounds.

Willis Stose Hilpert, Vice-President, The Miner Laboratories, Chicago, Ill.
Stereoisomeric Chlorimido Acid Esters.

James Wright Lawrie, Aurora, Ill.
The Chemistry of the Acetylidene Compounds.

Andrew Fridley McLeod, Instructor in Chemistry, Beloit College, Beloit, Wis.
On Aldol, Pentaerythrose, and the Action of Copper Acetate on the Hexoses.

1907 †Edith Ethel Barnard
The Catalysis of Imidoesters as Affected by the Presence of Non-Electrolytes and Electrolytes.

Katherine Blunt, Associate Professor of Home Economics, University of Chicago.
The Formation of Amidines.

Willey Denis, Research Assistant, Harvard Medical School, Cambridge, Mass.
On the Behavior of Various Aldehydes, Ketones, and Alcohols toward Oxidizing Agents.

Robert Anderson Hall, First Lieutenant, Infantry, American Expeditionary Forces, France.
The Action of Ammonia on Isourea Esters.

Louis Allen Higley, Professor of Chemistry, New Mexico College of Agriculture and Mechanical Arts, State College, N.M.
On the Behavior of Sodium and Sodium Alcoholates toward Various Esters.

William Horace Ross, Research Chemist, Bureau of Soils, Department of Agriculture, Washington, D.C.; Captain, Offense Division, Chemical Warfare Service, U.S.A., Edgewood Arsenal, Edgewood, Md.
On the Relation between the Radioactivity and the Composition of Thorium and Uranium Minerals.

Louis A. Test., Professor of General Chemistry, Purdue University, Lafayette, Ind.
The Rearrangement of o-Amino Phenyl Esters.

1908 George Cromwell Ashman, Professor of Chemistry, Bradley Institute, Peoria, Ill.
Studies in Radioactivity.

1909 Ernest Anderson, Associate Professor of Chemistry, Massachusetts State Agricultural College, Amherst, Mass. [on leave of absence]; Professor of Agricultural Chemistry, Transvaal University College, Pretoria, Transvaal.
The Action of Fehling's Solution on *d*-Galactose.

William Weldon Hickman, Professor of Chemistry, Assuit College, Assuit, Egypt.
The Catalysis of Imidoesters.

† Deceased.

1909 Winford Lee Lewis, Professor and Head of the Department of Chemistry, Northwestern University, Evanston, Ill.; Captain, Research Division, Chemical Warfare Service, U.S.A., Washington, D.C.

Peter Powell Peterson, Head of the Department of Soils in the College of Agriculture, University of Idaho, Moscow, Idaho.
Stereoisomerism of Chlorimido-Ketones.

Lemuel Charles Raiford, Professor of Chemistry, University of Iowa, Iowa City, Ia.
Chlorimido Quinones.

Herman Augustus Spoehr, Chemical Plant Physiologist, Carnegie Institution, Tucson, Ariz.
The Behavior of the Ordinary Hexoses toward Hydrogen Peroxide in the Presence of Alkaline Hydroxides as Well as of Various Iron Salts.

1910 Emma Perry Carr, Professor and Head of the Department of Chemistry, Mount Holyoke College, Mount Holyoke, Mass.
The Aliphatic Imidoesters.

Elbert Edwin Chandler, Professor of Chemistry, Occidental College, Los Angeles, Cal.
Ionization Constants of the Second Hydrogen Ion of Dibasic Acids.

Ira Harris Derby, Consulting Chemist, Republic Creosoting Co., Minneapolis, Minn.
Studies in Catalysis of Imidoesters, IV.

Stewart Joseph Lloyd, Professor and Head of the Department of Chemistry and Metallurgy, University of Alabama, University, Ala.
Studies in Radioactivity.

Alan W. C. Menzies, Professor of Chemistry, Princeton University, Princeton, N.J.
Studies in Vapor-Pressure.

John Colin Moore, Instructor in Chemistry, Toledo Heights High School, Chicago, Ill.
The Action of Water on Acyl Isoureas.

William Cabler Moore, Director of Research Laboratory, National Carbon Co., Cleveland, Ohio.
Studies in Organic Amalgams.

Fred Wilbert Upson, Professor and Head of the Department of Chemistry, University of Nebraska, Lincoln, Neb.
On the Action of Normal Barium Hydroxide on d. Glucose and d. Galactose.

1911 Thomas Bruce Freas, Associate Professor of Chemistry, Columbia University, New York, N.Y.
A Study of Thermostats.

John Foote Norton, Assistant Professor of Bacteriology, University of Chicago.
Simultaneous Reactions in Amidine Formation.

Harlan Leo Trumbull, Assistant Professor of Chemistry, University of Washington, Seattle, Wash.; Captain, Chemical Warfare Service, U.S.A., Edgewood Arsenal, Edgewood, Md.
The Molecular Rearrangement of Acid Chloramides and the Ionization of Their Salts.

Leroy Samuel Weatherby, Professor of Chemistry, University of Southern California, Los Angeles, Cal.
The Salt-Effects of the Nitrates and Sulphonates in the Catalysis of Imidoesters.

1911 Franklin Lorinzo West, Professor of Chemistry, Utah Agricultural College, Provo, Utah.
The Physical and Chemical Properties of Organic Amalgams.

1912 Paul David Potter, Chief Chemist, Sprague, Warner & Co., Chicago, Ill.
The Hydrates of Arsenic Pentoxide.

Charles Herman Viol, Chief Chemist, Standard Chemical Co., Pittsburgh, Pa.
The Chemical Properties and Relative Activities of the Radio-Products of Thorium.

1913 George Oliver Curme, Jr., Assistant Professor of Chemistry, University of Pittsburgh, and Research Chemist, Mellon Institute of Industrial Research, Pittsburgh, Pa.
The Thermal Decomposition of the Symmetrical Diaryl-Hydrazines.

John William Edward Glattfeld, Assistant Professor of Chemistry, University of Chicago.
The Oxidation of *d*-Glucose in Alkaline Solution by Air as Well as by Hydrogen Peroxide.

Paul Nicholas Leech, Research Chemist, American Medical Association, First Lieutenant, Sanitary Corps, New Haven, Conn.
The Molecular Rearrangement of Triaryl Methyl Hydroxylamines; a New Interpretation for the Rearrangement of Ketoximes.

Ethel Mary Terry, Assistant Professor of Chemistry, University of Chicago.
The Velocity Coefficient of Saponification of Ethyl Acetate.

1914 Harold Stanard Adams, Research Biochemist and Superintendent, Biochemical Plant of Squibbs & Sons, New Brunswick, N.J.
Studies in Overvoltage.

Arthur Wesley Martin, Professor of Chemistry and Physics, University of Nanking, Nanking, China.
Studies on Solutions in Anhydrous Formic Acid.

Agnes Fay Morgan, Assistant Professor of the Chemistry of Nutrition, University of California, Berkeley, Cal.
I. Viscosities of Various Methyl and Ethyl Imidobenzoates and of the Sodium Salts of Para and Meta Nitrobenzoyl-chloroamides in Moderately Concentrated Aqueous Solutions. II. The Molecular Rearrangement of Some Triaryl Methylchloroamines.

Harry Morrill Paine, Research Chemist, Drug and Dyestuffs Corporation, New York, N.Y.
The Effects of Salts on the Solubility of Other Salts: 1. The Solubility Relations of a Very Soluble Bi-univalent Salt. 2. The Ionization of Bi-bivalent Salts.

Harley Martin Plum, Chemist, Standard Chemical Co., Pittsburgh, Pa.
The Extraction and Separation of the Radioactive Constituents of Carnotite.

Bert Allen Stagner, Research Chemist, Mellon Institute of Industrial Research, Pittsburgh, Pa.
On the Molecular Rearrangements of Triarylmethyl Hydroxylamines.

Clare Chrisman Todd, Professor of Chemistry, Washington Agricultural College, Pullman, Wash.
The Action of Alkaline Hydrogen Peroxide on d. Galactose.

1915 Clifford Daniel Carpenter, Associate Professor of Chemistry, Teachers College, Columbia University, New York City.
The Addition Compounds of Organic Substances with Sulphuric Acid.

1915 Oscar Fred Hedenburg, Research Chemist, Mellon Institute of Indus trial Research, Pittsburgh, Pa.
On the Esters, as well as the Monomolecular β- and γ-Lactones of d-Mannonic and d-Gluconic Acids; On Ortho Bis-d-Galactonic Acid, d-Galactonic γ-Lactone and Its Mono-Hydrate.

Edmund Charles Humphery, Chemist, E. I. du Pont de Nemours Co., Wilmington, Del.
Surface Tension at the Interface between Two Liquids.

Townes Randolph Leigh, Professor of Chemistry, Georgetown College, Georgetown, Ky.
On Chlorimido Esters and Chlorimido Benzil.

Edwin Daniel Leman, Research Chemist, Carnotite Reduction Co., Chicago, Ill.
The Relation between the Alpha-Ray Activities and Ranges of Radioactive Substances.

Helen Tredway (Mrs. Evarts A. Graham), Mason City, Iowa.
The Thermal Decomposition of Diaryl Hydrazines.

Ernest Dana Wilson, Research Chemist and Superintendent, Graton and Knight Mfg. Co., Worcester, Mass.
The Structure of Complex Atoms.

1916 Groves Howard Cartledge, Professor of Chemistry, Davidson College, Davidson, N.C.; Lieutenant, Research Division, Chemical Warfare Service, U.S.A., Washington, D.C.
A Study of the Emanation Method of Determining Thorium.

Clyde Coleman, Research Chemist, Ault & Wiborg Co., Cincinnati, Ohio.
Further Studies on the Behavior of the Alkali Metal Formates in (Anhydrous) Formic Acid.

Ralph Edwin Hall, Research Chemist, Geo-physical Laboratory, Carnegie Institution, Washington, D.C.; Captain, Chemical Warfare Service, U.S.A., Edgewood Arsenal, Edgewood, Md.
The Periodic System and the Properties of the Elements. The Free Energy of Dilution. The Freezing-Point Lowerings of Some Salts of Various Types of Ionization and of Salt Mixtures.

Lawrence Melvin Henderson, Instructor in Chemistry, The University of Minnesota, Minneapolis, Minn.; First Lieutenant, U.S.A., A.E.F., France.
The Ratio of Mesothorium to Thorium in Minerals.

William Tudor Pearce, Professor of General Chemistry, North Dakota Agricultural College, Agricultural College, N.D.
Ionization and Solubility Relations of Salts of Higher Types, Intermediate Ions in Solutions of Unibivalent Salts and of Lanthanum Iodate, a Triunivalent Salt. II, Solubilities of Very Soluble Higher Type Salts.

Willard Allen Roberts, Instructor in Chemistry, Iowa State College, Ames, Iowa; Lieutenant, Sanitary Corps, U.S.A.
Studies on the Cobalt-Ammines.

Stanley Davis Wilson, Assistant Professor of Chemistry, Union Medical College, Peking, China.
The Effect of Added Salts upon the Velocity of Saponification of Ethyl Acetate by Sodium Hydroxide.

1917 Lester Aronberg, Research Chemist, Western Electric Co., Chicago, Ill.
The Spectrum of the Isotopes of the Lead. The Structure of the Bismuth Line $x = 4722$A.

1917 Ralph Lyman Brown, Lieutenant, Chemical Warfare Service, American Expeditionary Forces, France.
The Molecular Rearrangement of Sym. Di-triphenylmethylhydrazine.

Sidney Marsh Cadwell, Research Chemist, United States Rubber Co., New York, N.Y.; Captain, Headquarters, Chemical Warfare Service, U.S.A., Washington, D.C.
The Beckmann Rearrangement: Determinations of Minute Quantities of Gold.

Earl Claudius Hamilton Davies.
The Orientation of Molecules in the Surface of Liquids, the Energy Relations at Surfaces, Solubility, Adsorption, Emulsification, Molecular Association, and the Effects of Acids and Bases on Interfacial Tension.

Adeline Mae DeSale (Mrs. George K. Link), Instructor in Chemistry, Lawrence College, Appleton, Wis.
The Velocity of Rearrangement of Benzoylazid.

Milton Theodore Hanke, Research Instructor, Sprague Memorial Institute, University of Chicago.
The Oxidation of Maltose in Alkaline Solutions by Hydrogen Peroxide and by Air. The Preparation and Study of Maltobionic Acid.

Frank Hynes Reed, Chemist, Sherwin Williams & Company, Chicago, Ill.
Studies in Conductivity. (A) Some Common Errors in the Determination of the Conductivity of Solutions. (B) The Behavior of Mixtures of Two Salts Containing a Common Ion, in Anhydrous Formic Acid Solutions.

James Kuhn Senior, Research Chemist, Rockefeller Institute, New York City; First Lieutenant, Chemical Warfare Service, American Expeditionary Forces, France.
Molecular Rearrangements in the Triarylmethylazide and Triarylmethylhydrazine Series.

Herbert Johnson Smith, Associate Professor of Chemistry, Mississippi Agricultural and Mechanical College, Agricultural College, Miss.
Solubility Products of Carbonates.

Ralph Kempton Strong, Professor of Chemical Engineering, Oregon Agricultural College, Corvallis, Ore.
Mesothorium-One and Radium; Their Isotopism and Enrichment.

William De Garmo Turner, Professor and Head of the Department of Chemistry, School of Mines, University of Missouri, Rolla, Mo.
The Diffusion of Gases and the Density of Chlorine. A Search for Possible Isotypes of Chlorine.

1918 Denton Jacobs Brown, Assistant Professor of Chemistry, University of Nebraska, Lincoln, Neb.
The Velocity of Decomposition of Benzoyl Peroxide.

Frank Emerson Brown, Assistant Professor of Chemistry, Iowa State College, Ames, Iowa.
1. The Structure of the Surfaces of Liquids and Solubility as Related to the Work Done by the Attraction of Two Liquid Surfaces on Each Other. 2. A Standardization of the Method for the Determination of Surface Tension or Free Surface Energy by the Drop-Weight Method. 3. A Simple Apparatus for the Determination of Surface Tension.

Elmer Newman, Bunting, Research Chemist, Bausch and Lomb Optical Co., Rochester, N.Y.
Transport Numbers of Potassium, Sodium, and Calcium Formates in Anhydrous Formic Acid.

1918 George Lindenberg Clark, Lieutenant, Research Division, Chemical Warfare Service, U.S.A., Washington, D.C.
1. The Structure of the Surfaces of Liquids. 2. Secondary Valence and Werner's Coördination Number.

Wilby T. Gooch, Professor of Chemistry.
1. Effect of Light on the Velocity of Saponification of Ethyl Acetate. 2. The Velocity Coefficient of the Saponification of Methyl Acetate.

Homer Henry Helmick, Lieutenant, Sanitary Corps, U.S.A.
A New Method for the Determination of Thorium in Monazite Sand.

Herbert Hiram King, Professor and Head of the Department of Chemistry, Kansas State Agricultural College, Manhattan, Kan.
1. The Structure of Liquids: Adsorption at Liquid—Liquid Interfaces and the Partition of a Solute between Two Liquids. 2. The Structure of Liquids: Adsorption, Solubility and the Double Electric Layer.

Raymond David Mullinix, Research Chemist, International Filter Co., Chicago, Ill.
Potassium Permanganate. Studies in Conductivity IV.

Ralph Emory Nelson, Assistant Professor of Chemistry, Purdue University, Lafayette, Ind.; First Lieutenant, Chemical Warfare Service, U.S.A., Research Division, Washington, D.C.
The Coefficient of the Velocity of the Reaction between Sodium Hydroxide and Ethyl Acetate.

Stephen Popoff, Air Nitrates Corporation, Muscle Shoals, Ala.
Studies of Manganates and Permanganates. I. The Course of the Action between Manganese Dioxide, Potassium Hydroxide and Oxygen, and the Manufacture of Potassium Permanganate.

Edward Noel Roberts, First Lieutenant, Sanitary Corps, U.S.A.
Velocity of Saponification of Ethyl Formate.

Harry Clyde Trimble, Assistant Professor of Chemistry, University of North Dakota, University, N.D.
The Effect of Electric Currents in Attempts to Induce Molecular Rearrangements.

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1921/22

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MATHEMATICS, ASTRONOMY AND ASTROPHYSICS, PHYSICS CHEMISTRY

1921–22

THE UNIVERSITY OF CHICAGO PRESS
CHICAGO, ILLINOIS

CALENDAR FOR THE YEAR 1921–22

1921

June 11	Saturday	Alumni Day
June 12	Sunday	Convocation Sunday
June 13	Monday	College Day
June 14	Tuesday	Summer Convocation
June 15	Wednesday	Examinations for the Spring Quarter
June 16	Thursday	
June 17	Friday	
June 17	Friday	Spring Quarter ends
June 18	Saturday	Registration for the Summer Quarter
June 20	*Monday*	*Summer Quarter begins*
June 20–25		Examinations of the College Entrance Examination Board
July 4	Monday	Independence Day: a holiday
July 16	Saturday	Special Examinations for removal of deficiencies (work reported conditioned or incomplete) incurred during the last quarter of residence
July 26	Tuesday	Examinations for the First Term of the Summer Quarter
July 27	Wednesday	
July 27	Wednesday	First Term of the Summer Quarter ends
July 28	Thursday	Second Term of the Summer Quarter begins
Aug. 28	Sunday	Convocation Sunday
Sept. 1	Thursday	Examinations for the Second Term of the Summer Quarter
Sept. 2	Friday	
Sept. 2	Friday	Autumn Convocation Summer Quarter ends
Sept. 12–16		Examinations for Admission
Sept. 29	Thursday	Registration for the Autumn Quarter
Sept. 30	Friday	
Sept. 30	Friday	Special Examinations for all students returning for the Autumn Quarter who incurred deficiencies (work reported conditioned or incomplete) in the last quarter of residence
Oct. 1	*Saturday*	*Autumn Quarter begins*
Oct. 1	Saturday	Registration for the Autumn Quarter
Oct. 3	Monday	All classes meet
Nov. 24	Thursday	Thanksgiving Day: a holiday
Dec. 18	Sunday	Convocation Sunday
Dec. 20	Tuesday	Winter Convocation
Dec. 21	Wednesday	Examinations for the Autumn Quarter
Dec. 22	Thursday	
Dec. 23	Friday	
Dec. 23	Friday	Autumn Quarter ends

1922

Jan. 2	*Monday*	*Winter Quarter begins*
Jan. 28	Saturday	Special Examinations for removal of deficiencies (work reported conditioned or incomplete) incurred during the last quarter of residence
Feb. 22	Wednesday	Washington's Birthday: a holiday
Mar. 19	Sunday	Convocation Sunday
Mar. 21	Tuesday	Spring Convocation
Mar. 22	Wednesday	Examinations for the Winter Quarter
Mar. 23	Thursday	
Mar. 24	Friday	
Mar. 24	Friday	Winter Quarter ends
Mar. 25—April 2		Quarterly Recess
April 3	*Monday*	*Spring Quarter begins*
April 29	Saturday	Special Examinations for removal of deficiencies (work reported conditioned or incomplete) incurred during the last quarter of residence
May 4	Thursday	Annual Conference with Co-operating Schools
May 5	Friday	
May 30	Tuesday	Memorial Day: a holiday
June 10	Saturday	Alumni Day
June 11	Sunday	Convocation Sunday
June 12	Monday	College Day
June 13	Tuesday	Summer Convocation
June 14	Wednesday	Examinations for the Spring Quarter
June 15	Thursday	
June 16	Friday	
June 16	Friday	Spring Quarter ends

OFFICERS OF ADMINISTRATION

Harry Pratt Judson, President of the University, Harper Memorial Library, Room W11.

Ernest DeWitt Burton, Director of the University Libraries, Harper Memorial Library, Room M27.

Nathaniel Butler, Director of Co-operation with Secondary Schools, Cobb Lecture Hall, Room 11A.

Edgar Johnson Goodspeed, Secretary to the President, Harper Memorial Library, Room W11.

Walter A. Payne, University Recorder and Examiner, Cobb Lecture Hall, Room 5A.

Marion Talbot, Dean of Women, Cobb Lecture Hall, Room 9A.

Sophonisba Preston Breckinridge, Assistant Dean of Women, Cobb Lecture Hall, Room 9A.

Albion Woodbury Small, Dean of the Graduate School of Arts and Literature Cobb Lecture Hall, Room10½A.

Rollin D. Salisbury, Dean of the Ogden Graduate School of Science, Cobb Lecture Hall, Room 10½A.

David Allan Robertson, Dean of the Colleges of Arts, Literature, and Science, Cobb Lecture Hall, Room 14A.

David Harrison Stevens, Assistant to the Dean of the Colleges of Arts, Literature, and Science, Cobb Lecture Hall, Room 14A.

Percy Holmes Boynton, Cobb Lecture Hall, Room 14A; Frank Justus Miller, Classics 23; Edith Foster Flint, Elizabeth Wallace, Classics 16: Deans in the Colleges of Arts and Literature.

Henry Gordon Gale, Wellington Downing Jones, Cobb Lecture Hall, Room 10A; Horatio Hackett Newman, Ellis Hall, Room 24: Deans in the College of Science.

Nathaniel Butler, Dean of University College, Cobb Lecture Hall, Room 11A.

GENERAL INFORMATION

The organization of the University includes: the Graduate School of Arts and Literature; the Ogden Graduate School of Science; the Colleges (Senior, last two years, and Junior, first two years) of Arts, Literature, and Science; the Divinity School; the Law School; Courses in Medicine; the School of Education, including the College of Education, the University High School, and the University Elementary School; the School of Commerce and Administration; the Graduate School of Social Service Administration.

Faculty and equipment.—The faculty (exclusive of assistants) numbers three hundred and seventy-seven; the libraries contain over 600,000 bound volumes and 200,000 pamphlets (estimated). The University owns nearly one hundred acres of land in Chicago and has forty buildings.

Location of the University.—The University grounds lie on both sides of the Midway Plaisance between Washington and Jackson parks, six miles south of the center of Chicago. Electric cars, elevated trains, and the Illinois Central suburban service reach all railway stations. Mail and baggage service is provided at the Information Office of the University.

The University year is divided into quarters: the Autumn (October, November, December); the Winter (January, February, March); the Spring (April, May, to the middle of June); the Summer (from the middle of June, July, August). For the year 1921–22 the exact dates for the opening of the four quarters are: Summer Quarter, June 20, 1921; Autumn Quarter, October 1, 1921; Winter Quarter, January 2, 1922; Spring Quarter, April 3, 1922. Students are admitted at the opening of each quarter; graduation exercises are held at the close of each quarter.

The unit of work and of credit is a *major*, i.e., a course of instruction involving four or five recitations or lecture hours per week for a full quarter, or double that number of hours for a term of six weeks. A *minor* is one-half a major. Normal work is three majors per quarter, or nine per year of three quarters.

Degrees.—The University confers in the Graduate Schools of Arts, Literature, and Science the degrees of Doctor of Philosophy and of Master of Arts and of Science; in the Colleges of Arts, Literature, and Science, the degrees of Bachelor of Arts, of Science, and of Philosophy; in the Divinity School, the degrees of Bachelor of Divinity, of Master of Arts, and of Doctor of Philosophy; in the Law School, the degrees of Doctor of Law and of Bachelor of Laws; in the School of Education, the degrees of Bachelor of Arts in Education, of Philosophy in Education, and of Science in Education; in the School of Commerce and Administration, the degrees of Bachelor of Philosophy, of Master of Arts, and of Doctor of Philosophy; in the Graduate School of Social Service Administration, the degrees of Master of Arts in Social Service Administration, and of Doctor of Philosophy.

Fellowships, scholarships, student service, etc.—By virtue of endowments and special appropriations, fellowships and scholarships and service afford stipends or tuition to a number of able and deserving students. The University also maintains a bureau for securing outside employment.

DOCTORS OF PHILOSOPHY AS GUESTS OF THE UNIVERSITY

The President of the University, on recommendation of a Head of a Department, will welcome Doctors of Philosophy of the University of Chicago as well as of other universities as guests of the University, with the privilege of attending seminars and of carrying on research in the laboratories and libraries. There will be no charge except for laboratory supplies and a nominal laboratory fee for laboratory work. Arrangements should be made in advance with the President.

FEES FOR MATRICULATION, TUITION, ETC.

A. *Matriculation fee.*—The matriculation fee is $5.00 and is required of every student on entrance into the University.

B. *Tuition fee.*—

1. The tuition fee in the **Graduate Schools of Arts, Literature, and Science,** and the **Graduate School of Social Service Administration,** is $50.00 a quarter.

2. The tuition fee for students in the **Colleges of Arts, Literature, and Science** and the **College of Education,** and unclassified students, is $60.00 a quarter for regular work (three majors for a quarter); for a fourth major, in addition, $20.00.

3. The tuition fee for students in the **School of Commerce and Administration,** including materials fees in that school, is $70.00 a quarter; for students the **Law School,** $65.00 a quarter; for students in the **Medical Courses,** including laboratory fees, $75.00 a quarter; and for students in the **Divinity School,** $50.00 a quarter.

4. *All tuition and laboratory fees are due on or before the first day of each quarter, and are payable without extra fee up to the end of the fifth day of the quarter. All fees are payable to the Cashier,* Press Building, Room 1.

C. *Fines, etc.*—For failure to pay tuition fees within the first five days of the quarter a fee of $5.00 is added to the bill.

D. *Laboratory fee.*—Students in most laboratory courses pay a laboratory fee of $6.00 a major (M. or DMj. courses will be charged in proportion). In the Departments of Home Economics, Modeling and Ceramics, and Industrial Education, laboratory fees varying from $2.00 to $6.00 are charged for certain courses, depending on the nature of the courses. Twelve dollars ($12.00) is the maximum charge for laboratory work in any one department. In addition to the regular laboratory fee, students in laboratory courses are required to purchase at the office of the Cashier adequate breakage and supply coupon tickets to be deposited as follows: for courses in Chemistry, with the Curator of Kent Chemical Laboratory; for courses in Physiology, with the instructor in charge; for courses in Physiological Chemistry, with the instructor in charge; and for courses in Zoölogy, Anatomy, Botany, Pathology, and Hygiene and Bacteriology, at the laboratory supply store, Room 10, Botany Building.

New tickets must be purchased at the opening of each quarter, and a refund of the unused balance on the old tickets can be obtained at that time.

E. *A small materials fee* is charged in certain courses in Political Economy and Sociology.

F. *Gymnasium locker fee.*—For the use of a locker in the dressing-room of the gymnasium a fee of $1.00 per quarter in the men's gymnasium and $1.50 in the women's gymnasium is charged. A small fee is also charged for the use of the tennis courts.

G. *Graduation fee.*—The general graduation fee, including diploma, is $10.00. The graduation fee for Doctors of Philosophy, including diploma and hood, is $15.00.

ROOMS, BOARD, AND GENERAL EXPENSES

The University has thirteen residence halls for students, eight for women and five for men. Rooms in these halls rent for from $30 to $75 a quarter. The rental covers charges for heat, light, and care, except that in Drexel House the rooms are cared for by the students themselves. Rooms are for the most part single, but a few in each Hall may be occupied by two students. Application for rooms should be made to the University Cashier, who will, on request, send a diagram of the Halls showing prices of rooms. Each room is furnished with study-table, chairs, bookcase, bureau, mirror, chamber-ware, rug, bedstead, mattress, and bedding, with the exception that in Hitchcock Hall rugs are furnished by the students and in Drexel House bedding is furnished by the students. Towels must be furnished by the students. Rooms may not be subrented, nor can exchange or transfer of rooms be made except by permission of the Cashier.

A University House is organized in each Hall; each House has a Head, appointed by the President of the University, and a House Committee, elected by the members; also a House Counselor, selected from the Faculties of the University by the members of the House. The membership of the House is determined by election, and each House is self-governing under the general control of the University.

Six of the halls for women (Beecher, Kelly, Foster, Green, Greenwood, and Kenwood) have separate dining-rooms and parlors. The cost of board in these halls is $7.00 per week and board for the entire quarter is payable in advance on the opening day. All students living in these halls are required to take their meals there.

The table below furnishes an estimate of the annual expenses, exclusive of tuition and laboratory fees, for thirty-six weeks, of a student in the University residing within the quadrangles.

	Lowest	Average	Liberal
Rent and care of room	$ 90.00	$144.00	$288.00
Board	231.00	270.00	330.00
Laundry	45.00	60.00	75.00
Textbooks and stationery	30.00	51.00	72.00
Incidentals	45.00	75.00	120.00
Total	$441.00	$600.00	$885.00

An opportunity to share in co-operative housekeeping and thereby to reduce living expenses somewhat is offered at Drexel House, which accommodates sixteen women students who share in the preparation of meals and the care of the House. Room rent for each student is $30.00 a quarter, and the co-operative plan makes the cost of table board considerably less than is possible under other circumstances. Some experience in housekeeping and adaptability to group life are necessary. Correspondence with reference to rooms in Drexel House should be addressed to the Director of the Housing Bureau.

The University of Chicago maintains its Housing Bureau in order to assist students in finding the best accommodations obtainable in the University neighborhood. All rooms listed have been inspected and certain standards are maintained. Rooms on small inclosed courts are not listed, and all householders registered must rent exclusively to men, or exclusively to women. The use of a reception room at least two evenings a week must be provided for women students. Students are asked to co-operate by insisting on these requirements even if they do not engage their rooms through the Housing Bureau.

Upon arrival at the University, students should apply at once to the Housing Bureau for a list of rooms. Incoming students are especially cautioned against strangers who approach them at the station or on the streets and offer their services in securing rooms. Because of a general scarcity of housing facilities in Chicago at the present time, it is now more difficult to find satisfactory accommodations than was the case in past years.

Students may secure furnished rooms in the neighborhood of the University at prices ranging from $42.00 to $144.00 a quarter, and take their meals at the University or at nearby restaurants. Men occasionally find small rooms or dark rooms for less than $42.00 a quarter, but women usually have to pay $48.00 or more. Not less than $7.00 a week should be allowed for table board, and one can seldom find a room with outside light, drop light, study table, ample closet space, and a comfortable bed for less than $60.00 a quarter.

Desirable furnished rooms for light housekeeping are difficult to find. They range in price from $25.00 to $50.00 a month. The so-called kitchenettes in buildings in the vicinity of the University are small, usually dark, rooms with a kitchen table and gas plate, but never with running water. Rooms with kitchen privileges may be secured at the regular room rates with an additional charge of about $6.00 per quarter.

Furnished houses or apartments of from four to ten rooms vary in price from $50.00 to $150.00 per month. In the University neighborhood there are very few two- or three-room apartments and their rental, unfurnished, is $35.00 a month or more. The Housing Bureau lists only furnished houses and apartments.

Lists of rooms may be obtained at the office, Room 1, Press Building, about one week before the opening of each quarter. Lists should be obtained in person at this office. Renting by mail is not satisfactory and students are advised against it.

Board at the University may be obtained at Hutchinson Commons, the Ida Noyes refectory, and the Emmons Blaine lunch-room. Cafeteria service is provided, the cost of meals averaging about $7.00 per week.

FELLOWSHIPS AND SCHOLARSHIPS

The Trustees appropriate annually the amount of twenty-two thousand six hundred and thirty dollars ($22,630) for Fellowships in the Graduate Schools of Arts, Literature, and Science. These Fellowships range in value from $150, the tuition fees of a graduate student for three quarters, to $520, that is, $370 in addition to the tuition fees for three quarters. A limited number of Scholarships, covering a part or all of the tuition fees for three quarters, are also awarded annually.

Candidates for these Fellowships and Scholarships should send to the Deans of the Graduate Schools a record of their previous work and distinctions, degrees, and past courses of study, with copies of their written or printed work in the field of the department in which application is made. Application must be received at the Deans' offices *not later than March 1 of each year*, in order to be considered for the following year. Appointments will be made April 1.

Fellows may be called upon for assistance in teaching in the University, or for kindred work; but in no case will they be expected or permitted to devote so much time to this work as to prevent the successful prosecution of their own work as students. Fellows will not engage in outside work for compensation, unless by permission of the President. Except in rare cases, students will not be appointed to Fellowships until they have done at least one year of graduate work.

In addition to the Scholarships mentioned above, one graduate Scholarship, yielding a sum sufficient to pay the annual tuition fees, is annually awarded to the best student in each department graduated from the University of Chicago during the preceding year.

Full particulars concerning higher degrees, Fellowships, Scholarships, and other matters of interest to graduate students will be found in the *Circular of Information* of the Colleges and Graduate Schools of Arts, Literature, and Science, which will be sent upon application.

AID TO STUDENTS

Besides Fellowships and Scholarships various kinds of assistance are offered to those who need help, under the following heads: Prizes, University Service, Loans by the Students' Fund Society, and Outside Employment. The position of the University in a large city brings the decided advantage of providing many opportunities for employment. Through the University Employment Bureau many students are able to secure all of the outside employment for which they have time. For further details applicants should send for the circular *Awards and Aids*.

DEGREES

Graduate study may lead to a Master's or to a Doctor's degree under the conditions specified below:

I. THE MASTER'S DEGREE

Two degrees are conferred, viz., *Master of Arts* and *Master of Science*.

1. *Candidacy.*—Any member of the Graduate Schools who has been in attendance one quarter or more, and whose undergraduate course is equivalent

to that required for a corresponding Bachelor's degree in the University of Chicago,[1] and whose thesis subject has been accepted by the department concerned, may, on recommendation by the department or departments in which he is working, be enrolled, by vote of the Faculties of the Graduate Schools, as a candidate for a Master's degree. Application for admission to candidacy must be made on the blank provided for the purpose. This blank must be obtained by the applicant at the Dean's office, and the application must be on file in that office at least two months before the degree is conferred.

2. *Requirements.*—Students thus accepted as candidates will be given a Master's degree on fulfilment of the following requirements:

a) At least three quarters' residence at the University.

b) At least 8 majors of graduate work at the University of Chicago. These 8 majors need not be all in one department, but must be selected according to some rational plan approved by the Deans of the Graduate Schools at least six months before the degree is conferred. The individual courses must receive the approval of the heads of the department concerned.

c) A satisfactory dissertation on a subject approved by one of the departments in which the work is done.[2] The subject of the dissertation must be approved by the Head of the Department at least three months before graduation, and the dissertation in complete form must be submitted to the Department at least four weeks before the degree is conferred. This period may be lengthened to six weeks at the option of any department.

d) The delivery of three printed or typewritten copies of the dissertation to the University Library at least ten days before the Convocation at which the degree is to be conferred. Two of the copies must be bound.

e) A satisfactory examination on the work taken for the degree.

f) No course completed with a grade below C will count toward the Master's degree.

II. THE DEGREE OF DOCTOR OF PHILOSOPHY

The degree of *Doctor of Philosophy* is given, not on the basis of the completion of a certain amount of time spent upon a specified program, but as the recognition and mark of high attainments and ability in the candidate's chosen province, shown, first, by the production of a dissertation evincing the power of independent investigation and forming an actual contribution to existing knowledge; and, secondly, by the passing of examinations covering the general field of the candidate's subjects, with more detail in the case of the principal subject, with less detail in the case of the secondary subject or subjects.

1. *Candidacy.*—Any member of the Graduate Schools who has been in attendance one quarter or more, whose undergraduate course is equivalent to that required for a Bachelor's degree in the University of Chicago,[3] whose

[1] Attention is particularly called to the fact that the term "equivalent" in this connection refers to quantity only. It does not affect the question of the specific Master's degree (Arts or Science) to which a given student's work would lead. In case the candidate did not obtain his Bachelor's degree at the University of Chicago, he will present to the Examiner on blanks furnished for the purpose a detailed statement of his undergraduate work. The Examiner cannot always report upon these statements during the opening week of the quarter.

[2] In exceptional cases the Deans, upon the recommendation of the departments concerned, may accept an additional major in lieu of the dissertation.

[3] In case the candidate did not obtain his Bachelor's degree at the University of Chicago, he will present to the Examiner on blanks furnished for the porpose a detailed statement of his undergraduate work. The Examiner cannot always report upon these statements during the opening week of the quarter.

thesis subject has been accepted by the principal department, and who has a reading knowledge of two modern languages other than English, may, on recommendation by the principal department in which he wishes to take his degree, be enrolled, by vote of the Faculties of the Graduate Schools, as a candidate for the Doctor's degree. The languages other than English must be languages which contain important critical literature of the subject in which the candidate's principal work is done. They must be selected with the approval of the department of principal work and of the Dean, and a reading knowledge of the languages must be certified by the appropriate departments not less than one academic year (9 months) before the degree is conferred. Application for admission to candidacy must be made on the blank provided for the purpose. This blank must be obtained by the applicant at the Dean's office, and the application must be on file in that office before the close of the quarter preceding that in which the degree is conferred.

2. *Requirements.*—Students accepted as candidates will be given the Doctor's degree on the fulfilment of the following requirements:

a) At least three years of resident work in pursuance of an accepted course of study. The student may follow one of two plans. Plan I: The work offered in fulfilment of the requirements for the Ph.D. degree in any department is outlined by the Department and approved by the Dean, for each candidate, not later than the first quarter of his last year of residence work. The work required will include such courses in departments allied to that of principal work as may be deemed necessary by the principal department to obviate narrow specialization. The work is selected with regard to the needs of the individual student, with the double purpose (1) of giving him a knowledge of the relations of his principal subject to cognate branches of learning, and (2) of preparing him for productive scholarship. All courses offered in fulfilment of the requirement for the degree must be advanced courses, and a list of courses shall be submitted to the Faculties when the applicant is admitted to candidacy. Plan II: Under this plan the work offered must include one principal and either one or two secondary subjects. The amount of work required in the secondary subject or subjects is normally 9 majors. Candidates for the degree of Doctor of Philosophy may not, under this plan, take more than two-thirds of their work in one department, and may not take work which is to count toward the degree in more than three departments.

b) A satisfactory final examination upon the work done in preparation for the degree.

c) The presentation of a satisfactory dissertation upon a subject which has been approved by the Head of the Department in which the principal part of the candidate's work has been done.

d) A good command of literary expression and such knowledge of subjects considered fundamental as may be prescribed by the several departments.

3. *Dissertation.*—Each student is required to prepare a dissertation upon some topic connected with his principal subject. The dissertation must constitute an actual contribution to knowledge. Its subject must be submitted for approval to the Head of the Department at least twelve months before the date of the final examination. The dissertation itself must be submitted to the Head of the Department at least one month before the date of the final examination. This period may be lengthened to six weeks at the option of any department.

Ten days before the Convocation at which the degree is conferred, a typewritten copy of the dissertation, together with a certificate signed by the Head or acting Head of the Department that the copy, as submitted, is accepted for publication as the candidate's dissertation for the Doctor's degree, shall be filed in the office of the Deans of the Graduate Schools. Said copy may not be withdrawn from the office of the Deans of the Graduate Schools until the required one hundred copies are deposited in the Library.

The candidate shall deposit in the office of the Deans of the Graduate Schools a contract in legal form to the effect that he will furnish the General Library with one hundred copies (including two bound in half-roan) which shall fulfil in format, cover, title-page, and stock all the University requirements. (See special circular entitled *Dissertation Regulations*.)

Any one of the following three methods may be followed:

a) A signed statement may be filed in the Graduate Office from a publishing agency approved as to its technical efficiency by the University of Chicago Press, and also as to its professional responsibility by the department concerned, that the dissertation has been received and accepted for publication.

The one hundred copies furnished to the General Library must be separate prints. They must contain no other material and must be put in covers (ninety-eight in paper covers and two in half-roan).

b) The candidate may deposit with the Business Office a legal financial guaranty sufficient to enable the University of Chicago Press to print the required one hundred copies, including the binding of two copies in half-roan. This guaranty shall mature at the expiration of two years from the date of the conferring of the degree.

c) The candidate may at his own cost secure publication of the dissertation in the form prescribed by the University, in which case the degree will be conferred only after the delivery of the required one hundred copies to the General Library.

Additional dissertation regulations:

d) Upon recommendation of a department and approval of the Dean of the Faculty immediately concerned, a form of the Doctor's dissertation briefer than that received in satisfaction of requirements for the degree may be accepted for publication. For instance, the alternative form of publication may be an account of the method pursued in the investigation, together with an abstract of the evidence used and a complete summary of the conclusions reached; or it may be a single chapter, provided the same represents a distinct unit of investigation.

e) In case the briefer form of the Doctor's dissertation is accepted for publication, five typewritten copies of the complete dissertation are required for deposit in the library in addition to the printed copies.

f) In case the course provided for in *d*) is adopted, arrangements for the same are made in the Dean's office before the expiration of the term fixed for publication.

g) Clauses *d*)–*f*) are held to modify other rules governing publication of dissertation in the one detail of providing for acceptance of a printed abbreviation in the place of the complete dissertation.

4. *Final examination.*—Plan I (see 2, *a*), p. 10): After admission to candidacy the student may present himself for examination as soon as he has fulfilled (1) the requirements of the department and (2) the dissertation requirements

(see 3, p. 10). The examination will be conducted by a committee consisting of members of the department in which the degree is to be taken, and a representative of some other department, appointed by the Deans of the Graduate Schools. The candidate is required to prepare a typewritten or printed brief of his work, including an analysis of the dissertation, and to file six copies of the same with his Dean for distribution to the committee one week before the time set for the examination. In case of the examination in the secondary department, the statement should include the work in this department, and the statement for the final examination should include the work of both departments.

Plan II (see 2, *a*), p. 10): After admission to candidacy the student may present himself for examination in his secondary subject or subjects as soon as he has fulfilled the requirements of the department or departments concerned. He may present himself for the examination in his principal subject, or in both principal and secondary subjects if the examination in the latter has not been taken in advance (1) as soon as he has fulfilled the requirements of the department or departments concerned, and (2) after he has made satisfactory arrangements as regards his dissertation. The examination will be conducted by a committee consisting of the members of the principal department concerned, an appointed representative of the secondary department, or a representative of each of them if there are two, of any other members of the secondary department who may choose to attend, and a member of some other department appointed by the Deans of the Graduate Schools. If the examination in the secondary subject or subjects is separated from the examination in the principal subject, the two may not be held in the same quarter, nor within two months of each other.

5. *Non-resident work.*—After being admitted, the student may be allowed to substitute non-resident work for resident work to a limited extent, under conditions to be arranged in consultation with the Dean and the heads of the departments concerned.

6. *Work done in other universities.*—Graduate work done in another university will be accepted as equivalent to resident work in the University of Chicago, provided the institution in which the work was done is of high standing, and adequate evidence is furnished that the work done there was satisfactorily performed. Graduate work done in other institutions cannot reduce the residence requirement at the University of Chicago to a period less than one year.[1]

[1] In order to avoid misunderstandings, candidates for higher degrees should consult their Deans concerning all technical requirements for such degrees before application is made for admission to candidacy. In all cases candidates should consult early with the heads of the departments of their major and minor subjects.

THE DEPARTMENT OF MATHEMATICS

OFFICERS OF INSTRUCTION

Eliakim Hastings Moore, Ph.D., LL.D., Sc.D., Math.D., Professor and Head of the Department of Mathematics.

Herbert Ellsworth Slaught, Ph.D., Sc.D., Professor of Mathematics.

George William Myers, Ph.D., Professor of the Teaching of Mathematics and Astronomy, the School of Education.

Leonard Eugene Dickson, Ph.D., Professor of Mathematics.

Gilbert Ames Bliss, Ph.D., Professor of Mathematics.

Ernest Julius Wilczynski, Ph.D., Professor of Mathematics.

Jacob William Albert Young, Ph.D., Associate Professor of the Pedagogy of Mathematics.

Arthur Constant Lunn, Ph.D., Associate Professor of Applied Mathematics.

Mayme Irwin Logsdon, Ph.D., Instructor in Mathematics.

Ernest Bloomfield Zeisler, S.B., Associate in Mathematics.

Solomon Lefschetz, Ph.D., Associate Professor of Mathematics, University of Kansas (Summer, 1921).

Henry Blumberg, Ph.D., Assistant Professor of Mathematics, University of Illinois (Summer, 1921).

FELLOWS, 1921–22

Harry Scheidy Everett, S.M. Edgar D. Meacham, A.B.

GENERAL AIMS

The courses in Mathematics are intended for those studying mathematics as a part of a liberal education, for those expecting to apply mathematics in other sciences or in technology, for prospective teachers of mathematics or other sciences in secondary schools, colleges, and universities, and for workers and investigators in the most advanced fields of mathematics.

ARRANGEMENT OF WORK

The student will be aided in planning his work in Mathematics by the classification of courses (in the list given later) as primarily of the Junior College, the Senior College, or the Graduate School, and by the specific prerequisites named for each course. But the proper arrangement of work in mathematics is of such extreme importance that students are urged to consult instructors of the Department in planning their work. For graduate students a formal system of registration is in use which requires personal conference with the instructor of each course to be taken, and quarterly consultation with the departmental adviser selected by the student.

MATHEMATICAL SEQUENCES FOR UNDERGRADUATES

All courses offered by the Department of Mathematics or given numbers in its printed Announcements (called "mathematical majors" in what follows) may be used in mathematical sequences, except those whose numbers begin with 0.

Courses admissible for sequences in the Departments of Physics and Astronomy may also be used in mathematical sequences to an amount not greater than one-third of the total number of majors.

Principal sequences.—A principal sequence may consist of any nine admissible majors provided at least three mathematical majors are included whose numbers are higher than 17.

Secondary sequences.—A secondary sequence may consist of any six admissible majors provided at least one mathematical major is included whose number is higher than 14.

The following are given as illustrations of typical sequences:

MATHEMATICS

Principal Sequences

a) Courses 1, 2, 3, 18, 19, 20, 47, 48, 49.
b) Courses 1, 2, 3, 18, 19, 22, 31, 34, 38.

Secondary Sequences

a) Courses 1, 2, 3, 18, 19, 20.
b) Courses 1, 2, 3, 15, 22 or 28, 31 or 34.

SEQUENCES FOR PROSPECTIVE TEACHERS

Principal Sequences

a) Courses 1, 2, 3, 18, 19, 22, 31, 37, 40.
b) Courses 1, 2, 15, 22, and any five of: 28, 34, 37, 38, 40, School of Ed. Math. 2, 5.

Secondary Sequences

Courses 1, 2, 3, 15, 22 or 31, 37 or 40.

MATHEMATICS AND ASTRONOMY

Principal Sequences

a) Courses 1, 2, 3, 18, 19, 20, Astronomy and Astrophysics 5, 6, 7.
b) Courses 1, 2, 3, 18, 19, 22, Astronomy and Astrophysics 3A, 3B, 4.

Secondary Sequences

a) Courses 1, 2, 3, 15, Astronomy and Astrophysics 1, 7.
b) Courses 1, 2, 3, 15, Astronomy and Astrophysics 3A, 3B.

MATHEMATICS AND PHYSICS

Principal Sequences

a) Courses 1, 2, 3, 18, 19, 47, Physics 3, 4, 5, or 3S, 4S, 7.
b) Courses 1, 2, 3, 15, 22, 31, Physics 3, 4, 5, or 3S, 4S, 7.

Secondary Sequences

a) Courses 1, 2, 3, 15, Physics 3S, 4S.
b) Courses 1, 2, 3, 22, Physics 3S, 4S.

GROUPS OF COURSES

Certain Senior College and early graduate courses introductory to the higher mathematics may be grouped for reference as follows: (A) †Differential and integral calculus with applications (3Mjs.); (B) †Solid analytics; selected topics in geometry; theory of equations; determinants and elementary invariants; limits and series; (C) †Analytic mechanics (2Mjs.); vector analysis; celestial

mechanics (2Mjs.); (D) †Synoptic course in advanced mathematics, †differential equations, †theory of definite integrals, elliptic integrals, Fourier series and Bessel functions, elements of the theory of functions; (E) Synthetic projective geometry; analytic projective geometry; differential metric geometry; differential projective geometry; (F) Theory of numbers; theory of invariants; selected chapters of algebra; theory of substitutions with applications to algebraic equations.

NOTE.—The courses marked † are given annually; the other courses usually once in two years.

These courses and the special courses in the Higher Mathematics are intended to give the student a comprehensive view of modern mathematics, to develop him to scientific maturity, and to enable him to follow, without further guidance, the scientific movement of the day in mathematics, and, if possible, to take an active part in it by creative research.

The special and research courses vary from year to year. They may be classified, in general, as relating to (*a*) Algebra and Arithmetic; (*b*) Analysis; (*c*) Geometry; (*d*) Mechanics and Applied Mathematics; and (*e*) the Foundations and Interrelations of the Mathematical Disciplines as purely abstract deductive systems. Courses of type (*d*) are also offered by the Departments of Astronomy and Physics.

PREPARATION FOR TEACHING

Courses in the history and the teaching of Elementary Mathematics—Arithmetic, Algebra, Geometry, Trigonometry, Analytic Geometry, Calculus, Mechanics—are offered by this Department and the School of Education. These courses embody the conviction that elementary students need to have their mathematics made not easier but more perfectly intelligible and attractive.

To this end it is believed that teachers should more generally appreciate and utilize in instruction the unity of mathematics, as made up of various closely interrelated parts, and the character of mathematics, as an ideal science developed by abstraction from various more concrete domains.

A) *Secondary-school positions.*—Students who expect to teach mathematics as a major subject in secondary schools should complete at least the following courses in their undergraduate career: (1) Courses in pure mathematics: Trigonometry, College Algebra, Plane Analytic Geometry, Differential and Integral Calculus and Applications of Calculus, Theory of Equations, and the Synoptic course; (2) Courses in applied mathematics: Descriptive Astronomy, Mechanics, and General Physics; (3) The two courses, Principles of Education and Methods of Education, which may be taken either in the Junior College or in the Senior College; (4) Practice Teaching in Mathematics in the University High School, for which the foregoing courses in education are prerequisite; (5) A course in the Teaching of Secondary Mathematics and a course in the History of Secondary Mathematics.

B) *Minor collegiate positions.*—Those who look forward to teaching mathematics in normal schools and small colleges should as undergraduates complete at least the following courses: (1) The general courses in education and those in the history and teaching of mathematics mentioned in (3) and (5) above; (2) The content courses specified in (1) and (2) above, together with Advanced Calculus (3 majors).

Candidates for these positions should take at least one year of graduate work leading to the Master's degree in Mathematics and during this year should visit some of the college courses in Mathematics with the purpose of observing methods of teaching.

C) *University positions.*—Candidates for university positions should qualify for the Doctor's degree. Courses in the history of mathematics and in the principles and practice of education are strongly recommended.

HIGHER DEGREES

Master's degree.—Candidates for the Master's degree in Mathematics are expected, on the basis of a principal sequence of nine majors of undergraduate mathematics, to offer for examination eight approved courses of groups (A)–(E), including the elements of the theory of functions, and to present a satisfactory dissertation on an assigned topic closely related to the subject of one of the courses.

Degree of Doctor of Philosophy.—Candidates for the Doctor's degree with Mathematics as secondary subject are expected to offer for examination nine approved courses in advance of course 3.

Candidates for the Doctor's degree with Mathematics as principal subject are expected (1) to offer for examination the subjects covered by fifteen majors of initial courses of groups (B)–(F), including two of each of the types (*a*)–(*e*), and by a considerable body of special courses, in each case presumably most closely related to the subject of the doctoral dissertation, and (2) to present a dissertation, in finished form, embodying valuable results of mathematical inquiry. The subject of the dissertation may be a topic of pure or applied mathematics or of the history, philosophy, or pedagogy of mathematics.

MISCELLANEOUS INFORMATION

Clubs.—The Departmental Club meets fortnightly for the review of memoirs and books, and for the presentation of results of research. The club is conducted by the members of the Faculties of Mathematics and Mathematical Astronomy. Graduate students of the Departments are expected to attend and otherwise to participate in the meetings of the club.

The Junior Mathematical Club, with fortnightly meetings, is conducted by the graduate students of the Departments of Mathematics and of Astronomy and Astrophysics.

Library.—The library contains the more important works on mathematics (about 7,400 volumes) and has current issues and complete files of the leading periodicals.

Models.—The collection of models includes a set of Brill's models: plaster and thread models of quadric surfaces, plaster models of cubic and Kummer's quartic surfaces, models of cyclides and surfaces of constant positive and negative curvature, and thread models of three-dimensional projections of four-dimensional regular bodies.

Summer Quarter.—The courses of the Summer Quarter are planned with special reference to the needs of those who are able to spend only the summer in residence. The courses are arranged so as to enable the student to continue his

work progressively in successive summers, and so that the courses of four consecutive summers give a wide view of modern mathematics. The student who is obliged to leave before the close of the Summer Quarter may usually arrange to complete his work by correspondence.

Scholarship Examinations.—The competitive examinations for the Senior College Scholarship and for the Graduate Scholarship in Mathematics are held each Spring Quarter at times and places announced in the *Weekly Calendar*. Prospective candidates should confer with the Departmental Examiner in Mathematics. Files of papers set at previous Scholarship examinations are accessible in the Departmental Library. Candidates for the Senior College Scholarship will be examined on courses 1, 2, and 3; those for the Graduate Scholarship on courses 18, 19, 20, 23, 24, 31, 47, 48, and 49.

COURSES OF INSTRUCTION

I. JUNIOR COLLEGE COURSES

00. Advanced Algebra.[1]—A collegiate treatment of quadratic equations and other topics of the third semester of algebra of the secondary school. For students who offer only one unit of mathematics for entrance. Mj. Autumn, (———).

1. Plane Trigonometry.—Mj. Summer, Assistant Professor Blumberg; Autumn, 3 sections, Associate Professor Laves, Mrs. Logsdon and Mr. Zeisler; Winter, 2 sections, Associate Professor Laves and Mr. Zeisler; Spring, 2 sections, Mr. Zeisler and ———.

2. College Algebra.—Mj. Summer, Professor Wilczynski; Autumn, 2 sections, Associate Professor Young and Mrs. Logsdon; Winter, Professor Wilczynski; Spring, Associate Professor Young.

3. Plane Analytic Geometry.—Elements of plane analytics, including the geometry of the conic sections, with an introduction to solid analytics. Prerequisite: course 1. Mj. Summer, Associate Professor Lefschetz; Autumn, Associate Professor Young; Winter, 2 sections, Associate Professor Dickson and ———; Spring, Mr. Zeisler.

4A, 4B, Surveying (Astronomy 4A, 4B).—Prerequisite: course 1. Mj. Autumn and Spring, Associate Professor Laves.

5. Spherical Trigonometry with Applications to Astronomy (Astronomy 2).—Prerequisite: course 1. Mj. Winter, Associate Professor Laves.

II. SENIOR COLLEGE COURSES

15. Introductory Calculus for Students of Science.[1]—The elementary fundamental principles, methods, and formulas of differential and integral calculus; application to simple problems of geometry and the physical sciences. This course is intended primarily for students of physics and chemistry who do not wish to take the longer course in Calculus (courses 18, 19, and 20). Prerequisite: course 1 and course 2 or course 3. Mj. Autumn, Associate Professor Lunn.

18,[2] 19, 20. Calculus I, II, III.—A development of the three fundamental notions of the Calculus: the derivative, the anti-derivative, the definite integral, with especial emphasis on their geometric interpretations and their relations to problems in geometry, mechanics, and physics. Prerequisite: courses 1, 2, and 3. Three consecutive majors. Autumn, Winter, Spring, Professor Bliss.

18,[2] 19. Calculus I, II.—Prerequisite: courses 1, 2, and 3. Two consecutive majors. Autumn and Winter, Professor Slaught; Winter and Spring, Mrs. Logsdon.

[1] Limited-credit course: After a student has credit for 18 majors but less than 27, these courses will be credited at one-half major each; after he has credit for 27 majors they will not be credited at all.

[2] If a student has credit for course 15, credit will be given for course 18 only in case the latter is completed with the standing of B − or better.

18.[1] **Calculus I: Differential Calculus.**—Derivatives; maxima and minima; curve tracing; Maclaurin's and Taylor's Series; indeterminate forms; partial derivatives; applications to geometry and physics. Prerequisite: courses 1 and 3 unless 3 is taken simultaneously. Mj. Summer, PROFESSOR SLAUGHT.

19. Calculus II: Integral Calculus.—A course aimed at a comprehension of the nature of integration and of its applications to geometry and physics; solution of numerous problems; use of table of integrals. Prerequisite: course 18. Mj. Summer, ASSOCIATE PROFESSOR YOUNG.

22. Elementary Theory of Equations.—Numerical equations, determinants and symmetric functions, as outlined in courses 23 and 24. Text: Dickson's *Elementary Theory of Equations.* Prerequisite: Differential Calculus. Mj. Autumn, PROFESSOR DICKSON.

23. Solution of Numerical Equations.—Isolation of the real roots by graphic methods and by use of Sturm's functions; Newton's and Horner's methods of solution; algebraic solution of cubic and quartic equations. Text: Dickson's *Elementary Theory of Equations.* Prerequisite: Differential Calculus. M. [Not given in 1921–22.]

24. Determinants and Symmetric Functions.—With applications to systems of linear equations and the theory of elimination. Text and prerequisite as in course 23. Students may enter without course 23 if thoroughly familiar with college algebra. M. [Not given in 1921–22.]

24A. Determinants.—For senior college and first-year graduate students. M. Summer, First Term, PROFESSOR MOORE.

27. Units and Dimensions.—A study of the basic mathematical aspects of physical science. Primarily a survey of those experimental relations in mechanics, heat, and electromagnetism which involve universal constants, with the ensuing theory of derived units, dimensions, and similitude. In connection with illustrative problems some attention is given to methods of computation and the reduction of observations. Prerequisite: Calculus and General Physics. Mj. Summer, ASSOCIATE PROFESSOR LUNN.

28. Selected Topics in Mathematics.—Based on certain parts of the "Monographs on Topics of Modern Mathematics Relevant to the Elementary Field," edited by J. W. A. Young. Mj. Summer, ASSOCIATE PROFESSOR YOUNG.

29, 30. Projective Geometry I, II.—The fundamental notions of projective geometry treated both analytically and synthetically. The method of abbreviated notation and homogeneous co-ordinates. Theory of determinants and their application to the geometry of two and three dimensions. Projective and dualistic transformations and the simpler Cremona transformations. Notions of group and invariant. Prerequisite: courses 1, 2, 3, 18, 19. Two consecutive majors. PROFESSOR WILCZYNSKI. [Not given in 1921–22.]

31. Solid Analytic Geometry.—Co-ordinate geometry of curves and surfaces in three-dimensional space, in particular, those of the first and the second degree. Prerequisite: courses 3 and (unless taken simultaneously) 18. Mj. Summer and Spring, PROFESSOR DICKSON.

34. Limits and Series.—Definitions and fundamental properties of various types of limits. Prerequisite: Differential and Integral Calculus. Mj. Spring, ASSOCIATE PROFESSOR YOUNG.

Mathematics for Primary and Intermediate Grades (School of Education: Mathematics 1A).—M. Summer, Second Term; PROFESSOR MYERS.

Mathematics for Upper Grades and Junior High Schools (School of Education: Mathematics 1B).—M. Summer, First Term, PROFESSOR MYERS.

The Teaching of Secondary Mathematics (School of Education: Mathematics 2).—Mj. Autumn, ASSISTANT PROFESSOR BRESLICH; Winter and Spring, PROFESSOR MYERS.

History of Mathematics (School of Education: Mathematics 5).—Mj. Summer and Winter, PROFESSOR MYERS.

[1] If a student has credit for course 15, credit will be given for course 18 only in case the latter is completed with the standing of B – or better.

37. Critical Review of Secondary Mathematics.—A brief survey of the subject-matter of Secondary Mathematics from the modern point of view, aiming both to organize the theory of the whole scientifically and to gather the products of this work for use in teaching. Primarily for teachers, actual and prospective, but open also to others. Mj. Associate Professor Young. [Not given in 1921–22.]

38. Synoptic Course in Advanced Mathematics.—A general historical and logical survey of a considerable portion of pure and applied mathematics. Prerequisite: courses 1, 2, and 3. Mj. Professor Wilczynski. [Not given in 1921–22.]

Analytic Mechanics I, II (Astronomy 5, 6).—An introductory course. Prerequisite: Mathematics 18, 19. 2Mjs. Autumn and Winter, Associate Professor MacMillan.

40. Topics of Geometry.—The topics will be selected from the following: foundations of geometry, nature and value of geometric reasoning, methods of solution of geometric problems, limits in geometry; anharmonic ratio, complete quadrilateral, polars, duality, modern geometry of the triangle, geometric conics, and others. There will be much work in actual solution of problems. Prerequisite: entrance Plane Geometry. Associate Professor Young. [Not given in 1921–22.]

47. Differential Equations.—A study of the more common types of ordinary differential equations, especially those of the first and second orders, with emphasis on geometrical interpretations and applications to geometry, elementary mechanics, and physics. Prerequisite: courses 18, 19, and preferably 20. Mj. Autumn, Professor Slaught.

48. Elliptic Integrals.—A systematic development of the theory of indefinite integration, leading to elliptic integrals and the elements of elliptic functions, with attention to problems and applications. This course includes also an introduction to Fourier series. Prerequisite: courses 18, 19, 20, and preferably 47. Mj. Professor Slaught. [Not given in 1921–22.]

49. Theory of definite Integrals.—A course treating of the properties and methods of computing definite integrals, including a study of methods of approximation, improper definite integrals, Eulerian integrals, multiple integrals, with many problems and applications. Prerequisite: course 47 and preferably 48. Mj. Summer and Winter, Professor Slaught.

50. Fourier Series and Bessel Functions.—(*a*) A study of the properties of Bessel functions in connection with the solution of a variety of physical problems where they occur directly. (*b*) Trigonometric and Bessel series as solutions of partial differential equations. Byerly's "Fourier Series." Mj. Associate Professor Lunn. [Not given in 1921–22.]

51. Theory of Sound.—Dynamical theory of production, transmission and reception of sound. Analysis and synthesis of vibrations. Illustrations by acoustic apparatus and musical instruments. Analogies in electromagnetic oscillations. Mj. Winter, Associate Professor Lunn.

60. Synoptic Course in the Theory of Numbers.—An introduction to selected topics in the theory of numbers, with attention to the historical development. Prerequisite: Theory of Equations. Mj. Professor Dickson. [Not given in 1921–22.]

III. GRADUATE COURSES

Note.—Students should register for graduate courses only after consultation with instructors.

65–69. Reading and Research in Mathematics.—If in the judgment of the Department it is advisable that a student undertake definite mathematical reading and research not closely connected with any current lecture course or seminar, he will register for one of the following informal courses 65–69.

65. Reading and Research in Foundations of Mathematics and in General analysis.—Mj. or DMj. Professor Moore.

66. Reading and Research in Algebra and the Theory of Numbers.—Mj. or DMj. PROFESSOR DICKSON.

67. Reading and Research in Analysis.—Mj. or DMj. PROFESSOR BLISS.

68. Reading and Research in Geometry.—Mj. or DMj. PROFESSOR WILCZYNSKI.

69. Reading and Research in Applied Mathematics.—Mj. or DMj. ASSOCIATE PROFESSOR LUNN.

71. Theory of Numbers.—Introductory course. Theory of congruences, the quadratic reciprocity theorem, and the theory of quadratic forms. Mj. Autumn, 1922, PROFESSOR DICKSON. [Not given in 1921–22.]

74. Theory of Algebraic Numbers.—Prerequisite: course 71. Mj. Winter, 1923, PROFESSOR DICKSON. [Not given in 1921–22.]

81. Substitution Groups and Algebraic Equations.—An introduction to the theory of groups of substitutions and the Galois theory of algebraic equations, with applications to geometry. Text: Miller, Blichfeldt, and Dickson's *Theory and Applications of Finite Groups*. Mj. Spring, PROFESSOR DICKSON.

82. Finite Groups.—Selected topics on substitution groups, abstract groups, finite linear and collineation groups. Text as in course 81. Mj. Spring, 1923, PROFESSOR DICKSON. [Not given in 1921–22.]

84. Continuous Groups.—An illumination of the fundamental concepts and theorems of the Lie theory in connection with various classes of problems of geometry and differential equations. Mj. Autumn, PROFESSOR DICKSON.

91. Introduction to Higher Algebra.—Properties of matrices, invariant factors, and elementary divisors; algebraic theory of a single quadratic or bilinear form; theory of pairs of quadratic or bilinear forms. Geometrical applications. Based largely upon Bôcher's *Introduction to Higher Algebra*. Mj. Winter, PROFESSOR DICKSON.

93. Theory of Algebraic Invariants.—An introduction to the non-symbolic theory of invariants of binary forms, with applications to geometry, followed by an explanation of the symbolic notation, with practice in its use. Based on Dickson's *Algebraic Invariants*. Mj. Spring, 1924, PROFESSOR DICKSON. [Not given in 1921–22.]

94. Modern Higher Algebra.—Especially theory of matrices, bilinear and quadratic forms. Mj. PROFESSOR DICKSON. [Not given in 1921–22.]

98. Linear Algebras.—An introduction to the theory of hypercomplex numbers, with attention to quaternions, the relations of the theory to matrices, bilinear forms, and groups. Text: Dickson's *Linear Algebras*, 1914, Cambridge Tracts on Mathematics and Mathematical Physics. Mj. Autumn, 1923, PROFESSOR DICKSON. [Not given in 1921–22.]

101. Theory of Functions of a Real Variable.—A study of the existence theorems for implicit functions, ordinary and partial differential equations, and their applications in Analysis, especially to the Calculus of Variations. Mj. Autumn, PROFESSOR BLISS.

101A. Theory of Functions of a Real Variable.—The continuum of real numbers; point sets; cardinal number; order function; measure; derivatives; Riemann, Lebesgue and other integrals; generalization, including Hilbert space, function space, and General Analysis. Prerequisite: Calculus. The proficiency of a second year graduate student is desirable. Mj. Summer, ASSISTANT PROFESSOR BLUMBERG.

102. Ordinary Linear Differential Equations of the Second Order.—Existence theorems (real case), the analogy between linear algebraic and linear differential equations, theorems of comparison and oscillation, characteristic numbers and functions, expansion of arbitrary functions, Green's functions. Prerequisite: an elementary knowledge of the theory of functions of a real variable. Mj. [Not given in 1921–22.]

104. Calculus of Variations.—Examples illustrating the various types of problems. The differential equations of a curve which minimizes a definite integral in a space of two or more dimensions. Other properties of a minimizing curve as deduced by Legendre, Weierstrass, and Jacobi for the case of the plane. Conditions which insure the existence of a minimum. Isoperimetric problems and the more general problems of Lagrange and Mayer. An introduction to the theory of double integrals. Prerequisite: course 101. Mj. Winter, PROFESSOR BLISS.

105. Functions of Lines.—Special cases which occur in the calculus of variations and the theory of integral equations. The derivations of Volterra and the differentials of Fréchet, with applications to maxima and minima and implicit functions. The theory of composition of functions and the solution of general types of integral and integro-differential equations. Prerequisite: course 104. Mj. PROFESSOR BLISS. [Not given in 1921–22.]

106. Partial Differential Equations.—The geometrical theory of equations of the first order. Linear equations. Systems of equations of the first order. Introduction to equations of the second order. Applications to geometry and physics. Mj. Spring, PROFESSOR BLISS.

108. Differential Equations from the Standpoint of Lie.—The relations between continuous groups and differential equations. The Picard-Vessiot theory of linear differential equations. Mj. PROFESSOR BLISS. [Not given in 1921–22.]

111. Classes of Functions and Functional Operations in General Analysis.—Based on Moore's *Introduction to a Form of General Analysis*. The general analysis in question is the theory of systems of classes of functions, functional operations, etc., involving at least one general variable on a general range. A general variable is a variable entering the theory without direct characterization as to quality or range of variation. A real- and single-valued function ξ of a general variable p has as especially important particular instances: (I) a real number ξ, the variable p having only one value; (II) an n-partite real number $\xi=(\xi_1, \ldots, \xi_n)$, or point ξ in real space of n dimensions, the variable p having the values $p=1, 2, \ldots, n$; (III) an infinite sequence $\xi=(\xi_1\ \xi_2, \ldots, \xi_n, \ldots)$ of real numbers, the variable p having the values $p=1, 2, \ldots, n, \ldots$; (IV) a function ξ or $\xi(p)$ of the variable p on the linear interval $0 \leqq p \leqq 1$ of the real number system. The first part of this introductory course considers certain fundamental closure and dominance properties of classes of functions of a general variable, properties possessed in particular by the class: (I) of all real numbers; (II) of all n-partite real numbers; (III_0) of all numerical sequences converging to zero; (III_1) of all absolutely convergent series of real numbers; (IV) of all continuous functions of p on the interval $0 \leqq p \leqq 1$. The course presupposes a knowledge of the elements of the theory of functions of real variables. For second-year graduate students. Mj. PROFESSOR MOORE. [Not given in 1921–22.]

112. Hermitian Matrices of Positive Type.—Sketch of a new simple theory of linear integral equations in general analysis—a two-fold generalization of Hilbert's theory of limited linear, bilinear, and quadratic forms in infinitely many variables. For second-year, or more advanced, graduate students. M. Summer, First Term, PROFESSOR MOORE.

112, 113, 114. Hermitian Matrices of Positive Type in General Analysis, I, II, III.—A generalization of Hilbert's theory of limited bilinear and quadratic forms in infinitely many variables. For second-year, or more advanced graduate students. Three consecutive majors. Autumn, Winter, Spring, PROFESSOR MOORE.

115, 116. Integral Equations in General Analysis.—Application of the methods of course 111 to a study of the general Fredholm and Hilbert-Schmidt theories of integral equations. Two consecutive majors. PROFESSOR MOORE. [Not given in 1921–22.]

121. Theory of Functions of the Complex Variable.—Introduction to the algebra and calculus of complex numbers and their geometric representation;

conform representation. The theory of power series and the properties of analytic functions. Introduction to the theory of Riemann surfaces. Prerequisite: courses 47 and 49. Mj. Spring, PROFESSOR WILCZYNSKI.

122. Algebraic Functions.—The analytic character of an algebraic function and its geometrical representation by means of a Riemann surface. Abelian integrals on the Riemann surface, with especial attention to the hyperelliptic case. Abel's theorem. Introduction to the theory of the inversion of Abelian integrals. Prerequisite: course 121. Mj. PROFESSOR BLISS. [Not given in 1921–22.]

122A. Selected Chapters in the Elements of Algebraic Geometry.—Geometry on an algebraic curve from the transcendental viewpoint. Prerequisite: course 121. Mj. Summer, ASSOCIATE PROFESSOR LEFSCHETZ.

123. Elliptic Functions.—Elliptic integrals and the Weierstrassian theory of elliptic functions. Applications of elliptic functions. Mj. PROFESSOR BLISS. [Not given in 1921–22.]

130. Foundations of Geometry.—A critical study of geometry by the method of postulates based on the work of Hilbert and his successors. Mj. Spring, PROFESSOR MOORE. [Not given in 1921–22.]

141. Analytic Projective Geometry.—Analytic treatment of the projective properties of the straight line and of the conic sections. Prerequisite: familiarity with the fundamental concepts of projective geometry and a good knowledge of the calculus. Mj. [Not given in 1921–22.]

142. Higher Plane Curves.—General properties of algebraic curves. Special study of the curves of the third and fourth order. Mj. Winter, PROFESSOR WILCZYNSKI.

144. Line Geometry.—The line co-ordinates of Plücker and Klein. Complexes, congruences, and ruled surfaces. Prerequisite: course 31. Mj. Spring, PROFESSOR WILCZYNSKI.

145. Higher Geometry.—A general survey of the principal methods and results of recent geometric research. The various systems of co-ordinates and space elements, the rôle of the group concept, and the cultivation of space intuition by the use of models. Prerequisite: Differential Equations, Projective Geometry, and Solid Analytic Geometry. Mj. PROFESSOR WILCZYNSKI. [Not given in 1921–22.]

151. Metric Differential Geometry.—The application of the Calculus to the metric theory of twisted curves and surfaces in space. Prerequisite: course 31. Mj. PROFESSOR WILCZYNSKI. [Not given in 1921–22.]

154, 155. Projective Differential Geometry I, II.—This course gives a brief account of Lie's theory, with applications to the theory of invariants of systems of linear differential equations. The projective differential properties of plane and space curves, of surfaces and congruences, then present themselves as a result of interpreting this invariant theory geometrically. Text: Wilczynski's *Protective Differential Geometry of Curves and Ruled Surfaces.* (B. G. Teubner, Leipzig, 1906.) Prerequisite: an elementary knowledge of differential equations and projective geometry. Two consecutive majors, Winter, Spring, 1923, PROFESSOR WILCZYNSKI. [Not given in 1921–22.]

154. Projective Differential Geometry.—Mj. Summer, PROFESSOR WILCZYNSKI.

156. Theory of Plane Curves.—Projective and metric differential and integral properties. Texts: Salmon's *Higher Plane Curves* and Wilczynski's *Protective Differential Geometry of Curves and Ruled Surfaces.* Prerequisite: an elementary knowledge of differential equations and projective geometry. Mj. PROFESSOR WILCZYNSKI. [Not given in 1921–22.]

157. Theory of Ruled Surfaces and Space Curves.—Primarily from the point of view of projective differential geometry. Text: Wilczynski's *Protective Differential Geometry of Curves and Ruled Surfaces.* Prerequisite: course 156. Mj. PROFESSOR WILCZYNSKI. [Not given in 1921–22.]

158. Theory of Surfaces and Congruences, with special emphasis upon the projective differential properties.—Prerequisites: course 157. Mj. PROFESSOR WILCZYNSKI. [Not given in 1921–22.]

160. Vector Analysis.—The elements of vector algebra, vector differentiation and integration, and the linear vector function; illustrated by typical applications to geometry, mechanics, and physics. Prerequisite: courses 31 and 49. Mj. ASSOCIATE PROFESSOR LUNN. [Not given in 1921–22.]

162. Applications of Vector Analysis in the Theory of Electromagnetism.—Formulation of the Maxwell-Lorentz theory in terms of vector analysis. Hydrokinetic analogies and the geometry of scalar and vector fields. Fundamental problems in integration. Introductory study of vectors in four dimensions. Prerequisite: course 160. Mj. Summer, ASSOCIATE PROFESSOR LUNN.

163. Theory of Attraction and the Potential.—The potential function of gravitation and electrostatics; Laplace's equation, Green's function, and harmonic analysis; extensions to cases of heterogeneous media, with sketch of the abstract theory as related to linear differential equations of the second order. Emphasis will be laid on the solutions of illustrative problems. Pierce's *Newtonian Potential Function.* Prerequisite: courses 49 and 160. Mj. ASSOCIATE PROFESSOR LUNN. [Not given in 1921–22.]

164. Dynamics of Oscillatory Systems: Theory of Sound.—Mj. ASSOCIATE PROFESSOR LUNN. [Not given in 1921–22.]

166. Hydrodynamics.—Kinematics of continuous media and dynamical theory of typical forms of motion in perfect and viscous fluids, with special emphasis on analytic methods of general use in mathematical physics. Mj. ASSOCIATE PROFESSOR LUNN. [Not given in 1921–22.]

167. Theory of Elasticity.—The geometry of strain in a continuous medium, dynamic relations of stress and strain; detailed study of selected problems in the equilibrium and motion of elastic solids. Prerequisite: Advanced Calculus and Analytic Mechanics. Mj. ASSOCIATE PROFESSOR LUNN. [Not given in 1921–22.]

170. Probability and Statistics.—The theory of average and probability for finite and infinite sets of elements; the statistical treatment of observations and the method of least squares; introduction to statistical mechanics, with examples from the theories of molecules and electrons. Prerequisite: Differential Equations. Mj. ASSOCIATE PROFESSOR LUNN. [Not given in 1921–22.]

171. Statistical Mechanics.—This course deals with the mathematical methods used in the treatment of those physical theories where the magnitudes directly accessible to measurement are conceived as averages of multitudes of elements and physical laws are interpreted as examples of statistical regularity. A brief preparatory treatment of the notions of statistics and of the main features of the theory of probability, with some examples in geometry and kinematics, will lead to the main work of the course, in the kinetic theory of gases, the electron theory of metals, and some aspects of the theory of radiation. Prerequisite: thorough knowledge of the Calculus. Mj. ASSOCIATE PROFESSOR LUNN. [Not given in 1921–22.]

172. Partial Differential Equations of Mathematical Physics; the Conduction of Heat.—A study of certain typical linear partial differential equations occurring in the analytic representation of physical theories and of the functional expansions of solutions satisfying given boundary conditions, with special reference to the concrete phenomena and physical analogies from which the abstract theory has been generalized. Prerequisite: courses 49 and 160. Mj. ASSOCIATE PROFESSOR LUNN. [Not given in 1921–22.]

178, 179. Relativity and the Theory of Gravitation.—The first major will be devoted to the special or restricted principle of relativity of Einstein, its various applications to physical theory, and the mathematical form given it by Minkowski. The second major will be given to the Riemann geometry of curved hyperspace, four-dimensional vector analysis, and the Einstein theory of

the gravitational field. Prerequisite: Thorough preparation in Calculus and General Physics. Two consecutive majors, Autumn, Winter, Associate Professor Lunn.

181, 182, 183. Seminar on Foundations of Mathematics and General Analysis I, II, III.—Three consecutive majors. Autumn, Winter, Spring, Professor Moore.

184. Seminar on Algebra and the Theory of Numbers.—This course, intended primarily for students engaged in or accepted for doctoral research under the instructor may be taken also by others accepted by him as qualified to undertake research in Algebra or the Theory of Numbers. Mj. Summer, Professor Dickson.

Hour	Summer, 1921	Autumn, 1921	Winter, 1922	Spring, 1922
8:00	1. Plane Trigonometry (Blumberg) 18. Differential Calculus (Slaught) 24. Determinants, First Term (Moore) 122A. Selected Chapters of Algebraic Geometry (Lefschetz) 184. Seminar on Algebra and Theory of Numbers (Dickson) Sat. 8:00–10:00	1*a*. Plane Trigonometry (Zeisler) 47. Differential Equations (Slaught) 101. Functions of a Real Variable (Bliss) 181. Seminar I on Foundations of Mathematics and General Analysis (Moore) Sat. 8:00–10:00	1*a*. Plane Trigonometry (Zeisler) 49. Definite Integrals (Slaught) 104. Calculus of Variations (Bliss) 182. Seminar II (Moore) Sat. 8:00–10:00	1*a*. Plane Trigonometry (Zeisler) 20. Calculus III (Bliss) 144. Line Geometry (Wilczynski) 183. Seminar III (Moore) Sat. 8:00–10:00
9:00	2. College Algebra (Wilczynski) 49. Definite Integrals (Slaught) 101A. Functions of a Real Variable (Blumberg) 184. Seminar (Dickson) (See 8:00)	15. Introductory Calculus for Students of Science (Lunn) 18*a*. Calculus I (Bliss) 112. Matrices in General Analysis I (Moore) 181. Seminar I (Moore) (See 8:00)	19*a*. Calculus II (Bliss) 51. Theory of Sound (Lunn) 113. Matrices in General Analysis II (Moore) 182. Seminar II (Moore) (See 8:00)	3. Analytic Geometry (Zeisler) 114. Matrices in General Analysis III (Moore) 121. Functions of a Complex Variable (Wilczynski) 183. Seminar III (Moore) (See 8:00)
10:00	3. Analytic Geometry (Lefschetz) 27. Units and Dimensions (Lunn) 31. Solid Analytic Geometry (Dickson) 154. Projective Differential Geometry (Wilczynski)	2*a*. College Algebra (Logsdon) 18*b* Calculus I (Slaught) 22. Theory of Equations (Dickson) 178. Relativity and Theory of Gravitation I (Lunn)	3*a*. Analytic Geometry (Dickson) 19*b*. Calculus II (Slaught) 142. Higher Plane Curves (Wilczynski) 179. Relativity and Theory of Gravitation II (Lunn)	31. Solid Analytic Geometry (Dickson) 106. Partial Differential Equations (Bliss)
11:00	28. Selected Topics of Mathematics (Young) 112. Hermitian Matrices of Positive Type—First Term (Moore) 162. Applications of Vector Analysis to Electro-magnetism (Lunn)	1*b*. Plane Trigonometry (Logsdon) 84. Continuous Groups (Dickson)	2. College Algebra (Wilczynski) 91. Higher Algebra (Dickson)	81. Substitution Groups (Dickson)
12:30		2*b*. College Algebra (Young) 1*c*. Plane Trigonometry (Laves)		2. College Algebra (Young)
1:30	19. Integral Calculus (Young)	3. Analytic Geometry (Young) Intro. to Surveying 1:30 to 3:30 (Laves)	18. Calculus I (Logsdon) 1*b*. Plane Trigonometry (Laves)	19. Calculus II (Logsdon) 34. Limits and Series (Young) Advanced Surveying 1:30 to 3:30 (Laves)
2:30		00. Advanced Algebra (———)	3*b*. Analytic Geometry (———) Spherical Trigonometry (Laves)	1*b*. Plane Trigonometry (———)

THE DEPARTMENT OF ASTRONOMY AND ASTROPHYSICS
THE DEPARTMENT OF PHYSICS

OFFICERS OF INSTRUCTION

Edwin Brant Frost, A.M., Sc.D., Professor of Astrophysics; Director of the Yerkes Observatory.

†Sherburne Wesley Burnham, A.M., Sc.D., Professor Emeritus of Practical Astronomy at the Yerkes Observatory.

Edward Emerson Barnard, A.M., Sc.D., LL.D., Professor of Practical Astronomy at the Yerkes Observatory.

Forest Ray Moulton, Ph.D., Professor of Astronomy.

Kurt Laves, Ph.D., Associate Professor of Astronomy.

William Duncan MacMillan Ph.D., Associate Professor of Astronomy.

John Adelbert Parkhurst, S.M., Associate Professor of Practical Astronomy at the Yerkes Observatory.

Storrs Barrows Barrett, A.B., Assistant Professor of Astrophysics; Secretary and Librarian of the Yerkes Observatory.

Georges Van Biesbroeck, Dr.Eng., Assistant Professor of Practical Astronomy at the Yerkes Observatory.

Oliver Justin Lee, S.M., Ph.D., Instructor in Practical Astronomy at the Yerkes Observatory.

Dorothy Wilhelmina Block, A.B., Assistant in Stellar Spectroscopy.

VOLUNTEER RESEARCH ASSISTANTS

Ernest C. Bryant, Professor in Middlebury College (Summer, 1921).

John Paraskévopoulos, Assistant in National Observatory at Athens, 1919–21.

Charles E. Rogers, Professor in Trinity College (Summer, 1921).

INTRODUCTORY

The work of the Department of Astronomy and Astrophysics is divided into two parts:

(1) Work at the University, comprising: (*a*) elementary instruction in general Astronomy, both theoretical and practical; (*b*) preliminary training in the principles and methods of work underlying the science of Astrophysics (given in part in the Department of Physics); (*c*) graduate and research work in Celestial Mechanics.

(2) Graduate and research work in Practical Astronomy and Astrophysics in the Yerkes Observatory at Williams Bay, Wisconsin.

At the University, in the work given by Professor Moulton, Associate Professor Laves, and Associate Professor MacMillan, emphasis will be laid on the development of the mathematical principles and methods which form the basis of the physical sciences. In addition to the courses in Descriptive Astronomy, Introduction to Celestial Mechanics, and Analytic Mechanics, courses in Periodic Orbits and in the various other branches of Celestial Mechanics will be given within periods not exceeding three years. The most fundamental subjects will be

† Deceased.

arranged so as to recur at regular intervals, while other more special topics will vary from time to time. The general object of the instruction will be to give experience and preliminary training in the work of observation and reduction; to furnish the student an adequate mathematical basis for successful work in Celestial Mechanics, and to direct research work in Celestial Mechanics. The Departmental Club meets fortnightly for the review of memoirs and books and for the presentation of results of research. The club is conducted by the members of the Faculties of Mathematics and Mathematical Astronomy. Graduate students of Mathematical Astronomy are expected to attend regularly and, so far as possible, to participate actively in the meetings of the club.

At the Yerkes Observatory the advanced student is made familiar with modern methods of research in various branches of Practical Astronomy and Astrophysics. The rapid development of the latter science within the last two decades been fully recognized in the equipment of the Observatory; the special laboratory facilities make some investigations possible which cannot be carried on where the equipment is less complete. In general, the work in progress during the year 1921–22 will include: researches in solar physics with the spectroscope, spectroheliograph, and photoheliograph; micrometric observations of double stars, planets, satellites, nebulae, and comets; studies of photographic stellar spectra and determinations of motions in the line of sight; photography of stars, comets, nebulae, etc.; photographic investigations of stellar parallax; research in visual and photographic photometry; special astrophysical researches. The opportunity of taking part in these investigations is deemed of more advantage to the qualified student than set courses of instruction; but regular programs of work, with courses of collateral reading, will be laid out as conditions require. During the Summer Quarter illustrated lectures particularly intended for graduate students are given by members of the staff. The Astronomical Club also meets at intervals for the discussion of assigned topics in Astronomy and Astrophysics.

FACILITIES

For instruction in Practical Astronomy a students' observatory is maintained. It is equipped with a modern Warner & Swasey equatorial telescope of 6½ inches aperture, which is provided with a filar micrometer, a 5-inch refractor, a 3-inch Bamberg transit instrument, a Bamberg universal instrument, a Riefler sidereal clock, a chronometer, and various smaller accessories. The laboratory courses offered by the Department of Physics afford excellent preliminary training for the work in Astrophysics.

For a description of the Yerkes Observatory, see the *Annual Register* of the University of Chicago, Part V of this volume. An illustrated pamphlet of 24 pages, describing the observatory in detail, may be obtained on application.

DEGREES

The Master's degree.—Students working for a Master's degree in Astronomy are advised to choose three majors of graduate work in the Department of either Mathematics or Physics and six majors in the Department of Astronomy from courses numbered 5 to 10, 22, and 23. Those working for the Master's degree in Practical Astronomy or Astrophysics at the Yerkes Observatory are not

required to spend part of their time at the University, although this is advised where possible.

The degree of Doctor of Philosophy.—The courses prescribed for the Master's degree together with three other graduate courses will meet the requirement for the Doctor's degree where Astronomy is the minor subject.

Candidates for the Doctor's degree, with Astronomy as major subject, are expected to take a number of courses in Mathematics and Physics. Students intending to specialize in Mathematical Astronomy will be required to take Advanced Integral Calculus, Differential Equations, and Theory of Functions of a Complex Variable; students intending to specialize in the lines of Astrophysics will be required to take the work in Theoretical Physics, Advanced Experimental Physics, Sound and Light, and Physical Manipulation. The courses in Astronomy which will be required depend on the phase of the subject which the candidate elects for his work. Students specializing in Mathematical Astronomy are expected to spend six months at the Yerkes Observatory, and those working in Practical Astronomy and Astrophysics are expected to spend at least two quarters at the University.

COURSES AVAILABLE FOR UNDERGRADUATES

SEQUENCES

3A and B, Descriptive Astronomy; 2, Spherical Trigonometry, with applications; 5, 6, Analytic Mechanics; 7A and B, Practical Astronomy; 10, Spectroscopy and Astrophysics; 22, 23, Celestial Mechanics; Mathematics 3, Analytic Geometry; 18, 19, Calculus; Physics 3, Mechanics, Molecular Physics, Heat; 4, Electricity, Sound, and Light.

The Department offers no nine-major sequences.

SECONDARY SEQUENCES

I. Astronomy

Courses 3A, 3B, 2, 7A, 7B, 10.

II. Astronomy and Mathematics

Courses 3, 18, 19, in Mathematics, 5, 6, 22, in Astronomy.

III. Astronomy and Physics

Courses 3A, 3B, Physics 3, 4, Astronomy 7, 10.

COURSES OF INSTRUCTION

I. JUNIOR COLLEGE COURSES

1. Descriptive Astronomy (shorter course).—An elementary course, dealing with fundamental facts, principles, and methods. Frequent access to the students' observatory. Mj. Summer, 1:30, Associate Professor MacMillan; Autumn, 8:00, Professor Moulton; Spring, 8:00, Professor Moulton; 10:00, Associate Professor MacMillan.

2. Spherical Trigonometry with Applications to Astronomy and Geodesy. Mj. Winter, 2:30, Associate Professor Laves.

3A and 3B. Descriptive Astronomy (longer course; 1 not prerequisite).—A two-quarter course dealing with the fundamental facts and principles of Astronomy. Modern as well as classical methods and results are brought into full discussion. The observational side of the subject also is emphasized. Prerequisite: Plane Trigonometry. 2Mjs. Autumn and Winter, 10:00, Associate Professor MacMillan.

4A, 4B. Surveying (Mathematics 4A, 4B).—Mj. Autumn and Spring, 1:30–3:30, Associate Professor Laves.

II. SENIOR COLLEGE COURSES

5. Analytic Mechanics (Statics).—An introductory course. Prerequisite: Mathematics 18, 19. Mj. Autumn, 9:00, Associate Professor MacMillan.

6. Analytic Mechanics (Dynamics).—Prerequisite: Mathematics 18, 19. Mj. Winter, 9:00, Associate Professor MacMillan.

7. Spherical and Practical Astronomy.—Determination of time, latitude, and longitude. Prerequisite: Astronomy 1 and Mathematics 3., Associate Professor Laves.]Not given in1921-22.]

8. Practical Astronomy I.—Observations of binary stars and determination of their orbits. Mj. Spring, 7:30 p.m., Associate Professor Laves.

9. Practical Astronomy II.—Observation of satellites and determination of orbits of satellites. [Not given in 1921–22.]

10. Spectroscopy and Astrophysics (Physics 24).—A non-technical treatment of the growth of Spectroscopy, with applications to solar and stellar phenomena. [Not given in 1921–22.]

III. GRADUATE COURSES

12. The Sidereal Universe.—Prerequisite: Astronomy 1. [Not given in 1921–22.]

21. Advanced Mechanics.—Prerequisite: Astronomy 5, 6. Mj. Spring, Associate Professor MacMillan. [Not given in 1921–22.]

22. Introduction to Celestial Mechanics I.—Gravitational theory of sun's heat, central forces, potential and attraction of finite bodies, properties of conic section motion. Prerequisite: Mathematics 18, 19. Mj. Spring, 9:00 Associate Professor MacMillan.

23. Introduction to Celestial Mechanics II.—Determination of orbits, special cases of the problems of three bodies: the Lunar Theory geometrically considered; variation of the elements and absolute perturbations. Mj. [Not given in 1921–22.]

31–36. Research Courses at the Yerkes Observatory.—The Yerkes Observatory is open only to graduate students who have completed the necessary preliminary studies and have had the requisite experience in practical laboratory and observatory work. Students wishing to work at the Observatory should first consult the Director of the Yerkes Observatory, Williams Bay, Wis., and obtain his approval. DMj. or 3Mjs. each Quarter, Professors and Instructors resident at Yerkes Observatory.

41. Theory of Planetary Motion.—Prerequisite: Astronomy 22 and 23. Mj. Autumn, Professor Moulton. [Not given in 1921–22.]

42. The Lunar Theory.—Prerequisite: Astronomy 22 and 23, Mathematics 121. Mj. Winter, Professor Moulton. [Not given in 1921–22.]

43. Application of the Methods of Periodic Orbits to the Lunar Theory.—Prerequisite: Astronomy 42. Mj. Spring, 9:00, Professor Moulton.

44, 45, 46. Exterior Ballistics.—Mj. Autumn, Winter, Spring, 11:00.

47, 48, 49. Advanced Ballistics.—Mj., 10:00, Professor Moulton.

51, 52. Modern Theories of Analytic Differential Equations with Applications to Celestial Mechanics and Periodic Orbits I, II.—Properties of the solution of a general system of differential equations of the nth order as functions of the independent variable, of the parameters, of the initial values of the dependent variables. Solutions developed as power series in the independent variable, in the parameters, in the initial values of the dependent variables, by the Cauchy-Lipschitz process, by the Picard approximation process, by continued variation of parameters. Applications to elliptic and hyperelliptic functions and to

periodic solutions of the problem of three bodies. Linear equations with applications to hypergeometric functions. Linear equations with periodic coefficients. Mj. Autumn and Winter, 9:00, PROFESSOR MOULTON.

60. Periodic Solutions of the Problem of Three Bodies.—Mj. Spring, 8:00, PROFESSOR MOULTON. [Not given in 1921–22.]

70. Theory of Figures of Equilibrium of Rotating Fluid Bodies.—This is an advanced course, including Poincaré's and Darwin researches. Mj. PROFESSOR MOULTON. [Not given in 1921–22.]

80. The Problem of Three Bodies.—Mj. Summer, 2:30, ASSOCIATE PROFESSOR MACMILLAN; Autumn, PROFESSOR MOULTON.

81. The Problem of Three Bodies.—Mj. Winter, 8:00, PROFESSOR MOULTON.

82. The Problem of Three Bodies.—Mj. PROFESSOR MOULTON. [Not given in 1921–22.]

CONSPECTUS OF COURSES OFFERED BY THE DEPARTMENT OF ASTRONOMY, 1921–22

Hour	Summer, 1921	Autumn, 1921	Winter, 1922	Spring, 1922
7:00				
8:00		1. Descriptive Astronomy (Moulton)		1. Descriptive Astronomy (Moulton)
9:00		5. Analytic Mechanics (MacMillan) 51. Modern Theories of Differential Equations I (Moulton)	6. Analytic Mechanics (MacMillan) 52. Modern Theories of Differential Equations II (Moulton)	22. Celestial Mechanics I (MacMillan) 43. Periodic Solutions in the Lunar Theory (Moulton)
10:00		3A. Descriptive Astronomy (MacMillan) 47. Advanced Ballistics (Moulton)	3B. Descriptive Astronomy (MacMillan) 48. Advanced Ballistics (Moulton)	1. Descriptive Astronomy (MacMillan) 49. Advanced Ballistics (Moulton)
11:00		44. Exterior Ballistics (———)	45. Exterior Ballistics (———)	46. Exterior Ballistics (———)
1:30	1. Descriptive Astronomy (MacMillan)	4A. Intro. to Surveying 1:30 to 3:30 (Laves)		4B. Advanced Surveying (Laves) 1:30 to 3:30
2:30	81. The Problem of Three Bodies (MacMillan)		2. Spherical Trigonometry with applications to Astronomy and Geodesy (Laves)	
7:00 P.M.				8. Practical Astronomy 7:30 P.M. (Laves)

31–36 Research courses at the Yerkes Observatory.

THE DEPARTMENT OF PHYSICS

OFFICERS OF INSTRUCTION

Albert Abraham Michelson, Ph.D., Sc.D., LL.D., F.R.S., Professor and Head of the Department of Physics.
Robert Andrews Millikan, Ph.D., Sc.D., Professor of Physics.
Henry Gordon Gale, Ph.D., Professor of Physics.
Harvey Brace Lemon, Ph.D., Assistant Professor of Physics.
Arthur Jeffery Dempster, Ph.D., Assistant Professor of Physics.
Leonard B. Loeb, S.B., Ph.D., National Research Fellow in Physics.
John Preston Minton, S.B., Ph.D., National Research Fellow in Physics.
Fabian Miller Kannenstine, S.B., Assistant in Physics.
Alfred H. Fischer, A.M., Assistant in Physics.
Lawrence E. MacAllister, A.B., Assistant in Physics.
Forrest G. Tucker, A.M., Assistant in Physics.
Vern Oliver Knudsen, A.B., Assistant in Physics.
Ira Sprague Bowen, A.B., Assistant in Physics.
Lloyd W. Taylor, A.B., Assistant in Physics.
Edward Blankenstein, M.S., Assistant in Physics.
Marshall Ney States, A.B., Assistant in Physics.
Roscoe E. Harris, S.B., Assistant in Physics.
Edward Stone Akeley, A.B., Assistant in Physics.
George Spencer Monk, S.B., Assistant in Physics.

Ludwik Silberstein, Ph.D., Physicist, Eastman Kodak Company (Summer, 1921).

FELLOWS, 1921–22

James Milton Eglin, A.B. William Vermillion Houston, A.B.
Robert Orland Hutchinson, A.B.

INSTRUCTIONAL WORK

The instructional work in Physics is directed toward the following ends: (1) the training of original investigators in physics; (2) the training of men competent to fill college and university positions as teachers of physics; (3) the training of teachers of physics for secondary schools; (4) the training of pre-engineering and premedical students for later professional work; (5) the training of the general student in scientific methods of work and in the understanding of the place of physical science in the modern world. From the most elementary to the most advanced courses the laboratory and the problem method of instruction are emphasized.

FACILITIES

The Ryerson Physical Laboratory has been enlarged and remodeled with especial reference to offering the best facilities for research work. The entire lower floor and basement are given up to private research-rooms. A well-equipped shop, with skilled instrument-makers, furnishes opportunity for the

construction of special pieces of research apparatus. The equipment has been selected with reference to the needs of research, and includes spectroscopic instruments of highest power, electrical apparatus for work in alternating and direct currents through all ranges of potential, and appliances for high- and for low-temperature work, including a liquid-air plant. The library of the Department is well equipped for research purposes. A Physics Club is conducted by the members of the Department, and meets regularly for the discussion of the results of research work done in the Ryerson Laboratory and elsewhere.

COURSES AVAILABLE FOR UNDERGRADUATE SEQUENCES

3, Mechanics; 4, Electricity; 5, Heat, Sound, and Light; 3S, Mechanics, Molecular Physics, and Heat; 4S, Electricity, Sound, and Light; 7, Lecture Demonstrations in Physics; 9, Elementary Wireless Telegraphy; Mathematics 7, 8, 9, Applied Mathematics (see under Mathematics Department); 11, Heat and Molecular Physics; 12, Light; 13, Electricity and Magnetism; 14, Pedagogy of Physics; 15, Mechanics and Wave-Motion; 16, 17, 18, 19, Experimental Physics; 20, Physical Manipulation; 21, Analytic Mechanics (Astronomy 5, 6); Education 62, Educational Psychology; 1, Principles of Education; Astronomy 3, Descriptive Astronomy (two majors); Mathematics 18, 19, Calculus.

Graduate courses in the Department may be substituted for courses 10 to 19 by students who have the prerequisites.

PRINCIPAL SEQUENCES

a) Courses 3, 4, 5, or 3S, 4S, 7, and any six majors chosen from courses 10 to 13; 15 to 19.

Physics and Mathematics

b) Courses 3, 4, 5, or 3S, 4S, 7, and any six majors from the following: Mathematics 18, 19; Astronomy 5, 6, and Physics 10 to 13; 15 to 18.

Teacher's Sequences

c) Courses 3, 4, 5, 7, or 3S, 4S, 7; 11, 14, 20; Education 62 and Philosophy 7.

Physics and Astronomy

d) Courses Physics 3, 4, 5, or 3S, 4S, 7; Astronomy 3 (two majors), with four majors selected from Physics 11–18, and Mathematics 18, 19.

Physics and Chemistry

e) Courses Physics 3, 4, 5, or 3S, 4S, 7; Chemistry 2S, 3S, and four majors selected from Physics 11–18, 18, and Mathematics 18, 19.

In any of the foregoing sequences graduate courses numbered 31 to 69 may be substituted for courses 10 to 18 by students who have the required prerequisites.

SECONDARY SEQUENCES

a) Courses 3, 4, 5, or 3S, 4S, 7, and three advanced majors in Physics.

b) Courses 3, 4, 5, or 3S, 4S, 7, and three majors from the following: 10 to 69, Astronomy 3 (two majors), Chemistry 2S, 3S; Mathematics 18, 19.

DEGREES

All candidates for the S.B. degree who elect their major work in Physics are required to take courses 3, 4, and 5, and either six majors selected from courses 7, 10, 11, 12, 13, 15, 16, 17, 18, 19, 24, and 28, or three of these and three Senior College courses in one of the following departments: Mathematics, Astronomy, Chemistry, Geology, or Geography.

The Master's degree.—Candidates for the Master's degree in Physics are required to take eight majors in Physics and related subjects, and to present in addition a dissertation embodying the results of a laboratory problem. Course 7 and all courses in the Department numbered 10 or above, except course 20, will be counted in satisfaction of this requirement, but at least three majors selected from courses 10, 11, 12, 13, and 15 must be included.

The degree of Doctor of Philosophy.—Candidates for the Doctor's degree with Physics as a minor subject must take six of the following courses: 10, 11, 12, 13, 15, 16, 17, 18, 19, 24, 28, and three additional majors of graduate work. When Physics is one of two minor subjects, the courses must be arranged by consultation with the Department.

All candidates for the Doctor's degree with Physics as the major subject must take the following courses: 10, 11, 12, 13, 15, and 28, or their equivalent; three majors selected from courses 16, 17, 18, 19, 37, 38; courses 31–36, and three additional graduate courses selected by the student. Each candidate must also present a dissertation embodying the results of original research in some subject approved by the Department. The time required for the dissertation work generally varies from three to six quarters.

PREPARATION FOR TEACHING

Students preparing to teach Physics in secondary schools are expected to have completed courses 3, 4, 5, 14, 28, and not less than four of courses 10, 11, 12, 13, 15, 16, 17, 18, 19, and 24. See also courses in Physics in the School of Education.

LABORATORY FEE

There is a laboratory fee of $6.00 for all major courses involving laboratory work in the Department of Physics.

COURSES OF INSTRUCTION

I. JUNIOR COLLEGE COURSES

1. Elementary Physics.[1]—A first course in the elements of Physics designed primarily for students who do not present entrance Physics. Prerequisite: Algebra and Plane Geometry, one unit each. DM. Summer, First Term, 1:30–4:30, MR. MONK; Mj. Autumn, 5 sections, 9:00–11:00, 11:00–1:00, 1:30–3:30, 3:30–5:30, 7:00–9:00, MR. FISCHER AND MR. HARRIS.

2. Elementary Physics.[1]—A continuation of the preceding course, covering the subjects of electricity, sound, and light. Prerequisite: course 1. DM. Summer, Second Term, 1:30–4:30, MR. MONK; Mj. Winter, 9:00–11:00, 11:00–1:00, 1:30–3:30, 3:30–5:30, 7:00–9:00, MR. FISCHER AND MR. HARRIS.

[1] Limited-credit course: After a student has credit for 18 majors but less than 27, these courses will be credited at one-half major each; after he has credit for 27 majors they will not be credited at all.

3. Mechanics.—A general college course in mechanics presented mainly from the experimental point of view, but including one demonstration lecture each week. Prerequisite: entrance Physics or course 2. Mj. Autumn, 6 sections, 7:00–9:00, 9:00–11:00, 11:00–1:00, 1:30–3:30, 3:30–5:30, 7:00–9:00, Assistant Professor Lemon, Mr. States, Mr. Tucker, Mr. Taylor, Mr. Blankenstein, and Mr. Knudsen; Winter, 4 sections, Mr. States, Mr. Akeley, Mr. Monk, Mr. McAllister.

4. Electricity.—A general college course in electricity, presented mainly from the experimental point of view, but including one demonstration lecture each week. Prerequisite: course 3. Mj. Winter, 5 sections, 9:00–11:00, 11:00–1:00, 1:30–3:30, 3:30–5:30, 7:00–9:00, Assistant Professor Lemon, Mr. Tucker, Mr. Taylor, Mr. Blankenstein, and Mr. Knudsen; Spring, 4 sections, Mr. States, Mr. Akeley, Mr. Monk, Mr. McAllister.

5. Heat, Sound, and Light.—A general college course in heat, sound, and light, presented mainly from the experimental point of view, but including one demonstration lecture each week. Prerequisite: course 4. Mj. Spring, 5 sections, 9:00–11:00, 11:00–1:00, 1:30–3:30, 3:30–5:30, 7:00–9:00, Assistant Professor Lemon, Mr. Tucker, Mr. Taylor, Mr. Blankenstein, and Mr. Knudsen.

3S. Mechanics, Molecular Physics, and Heat.—A general college course in mechanics, molecular physics, and heat presented from the experimental point of view, not containing demonstration lectures. Prerequisite: entrance Physics or course 2 and Trigonometry. Mj. Summer, 3 sections, 7:00–9:00, 10:00–12:00, 1:30–3:30, Mr. McAllister and Mr. States; Spring, 1 section, 8:00–10:00, Mr. Fischer.

4S. Electricity, Sound, and Light.—A general college course in electricity, sound, and light presented from the experimental point of view, not containing demonstration lectures. Prerequisite: course 3S or courses 3 and 4. Mj, Summer, 3 sections, 7:00–9:00, 10:00–12:00, 1:30–3:30, Mr. Knudsen and Mr. States; Autumn, 2 sections, 8:00–10:00, 12:30–2:30, Mr. Akeley, Mr. Monk.

II. SENIOR COLLEGE COURSES

7. Lecture Demonstration Course.—A course of demonstration lectures covering the entire field of Physics designed to supplement courses 3S and 4S. Especial attention is given to modern points of view; the kinetic theory of heat, the atomic theory of electricity, and the electrical theory of matter receiving especial attention. The attempt is made to repeat a majority of the classical demonstrations of Kelvin, Faraday, Thomson, and others. This course includes the demonstration lectures of courses 3, 4, and 5. It may be registered for during the Autumn, Winter, and Spring, University College. 1 minor each quarter. Students so registering or students taking this course in the summer receive Senior College or graduate credit. Prerequisite: courses 3S and 4S or their equivalent. Mj. Summer, 9:00, Mr. Taylor; Autumn, Winter, Spring, 9:00, Sat., Assistant Professor Lemon.

9. Elementary Wireless Telegraphy.—A course of lectures and laboratory work consisting of elementary consideration of the fundamental laws and their applications to the circuits of modern wireless telegraph systems. Experimental adjusting of wireless telegraph circuits and practice in receiving the Continental code. Prerequisite: courses 3 and 4. Mj. Summer, 8:00–10:00, Mr. Kannenstine.

11. The Kinetic Theory.—A lecture course for advanced and graduate students, covering the kinetic theory, of gases, liquids, and solids. Prerequisite: Physics 4S or 5 and Calculus. Mj. Autumn, 9:00, Professor Millikan.

12. Light.—A lecture course for advanced students covering the more important sections of geometrical and physical optics. Prerequisite: Physics 4S or 5 and Calculus. Mj. Winter, 9:00, Dr. Loeb.

13. Electricity and Magnetism.—A course of advanced work in Theoretical Electricity and Magnetism, with many applications to electrical and magnetic apparatus and measurements. Prerequisite: Physics 4S or 5 and Calculus. Mj. Winter, 10:00, Assistant Professor Dempster.

16. Experimental Physics (Advanced): Molecular Physics and Heat.—A course of advanced laboratory work involving the determination of vapor pressures and densities, coefficients of friction of gases and liquids, molecular electrical conductivities, freezing- and boiling-points, latent and specific heats, high and low temperatures, radioactive constants, etc. Prerequisite: course 4S or 5. Mj. Spring, 2:30–4:30, Professor Millikan and Assistant Professor Dempster.

17. Experimental Physics (Advanced): Light.—A course of advanced laboratory work in Light, consisting of accurate measurements in diffraction, dispersion, interference, and polarization. Prerequisite: course 4S or 5. Mj. Summer, 8:00–10:00, Professor Gale and Mr. Taylor; Autumn, 8:00–10:00, Mr. Taylor.

18. Experimental Physics (Advanced): Electricity and Magnetism I.—Laboratory work of the same grade as courses 16 and 17, but consisting of measurements in Electricity and Magnetism. Prerequisite: Physics 4S or 5. Mj. Summer and Winter, 2:30–4:30, Mr. Kannenstine.

19. Experimental Physics (Advanced): Electricity and Magnetism II.—Laboratory work accompanied by lectures consisting of the theory and operation of dynamos, motors, transformers, wireless-telegraph apparatus. Prerequisite: Physics 4S or 5. Mj. Spring, 3:30–5:30, Mr. Kannenstine.

20. Physical Manipulation.—A series of exercises not provided in the regular courses of Experimental Physics, but important to the teacher or advanced student. It consists of the following groups:

Group A. *Shopwork* includes the cutting, filing, drilling, tapping, soldering, and polishing of metal, screw-cutting, and elementary lathework.

Group B. *Glasswork* includes the cutting, grinding, drilling, polishing, and testing of glass.

Group C. *Glass-blowing* includes the simpler processes in glass-blowing, such as cutting, bending, and joining of tubes, blowing bulbs, sealing in electrodes, etc.

Group D. *Chemical Processes and Physical Preparations* include the silvering of glass, cleaning and distillation of mercury, preparation of fibers for suspension, and materials useful in experimental work.

Group C only M. First Term. Repeated Second Term. Registration permitted only on consultation with instructor. Summer, 1:30–3:30, Dr. Loeb.

21. Radioactivity and Discharge through Gases.—A laboratory course for Senior College and Graduate students. Mj. Autumn, Assistant Professor Dempster.

22. Electrical Circuits.—A course of lectures accompanied by occasional demonstrations on electric circuit phenomena, including, magnetic fields, electromagnetic induction, oscillatory circuits, vacuum tube circuits, induction in iron, alternating currents, electric filters, transmission in lines. Prerequisite: Physics 3, 4, 5 and Calculus. Mj. (or M. either Term), Summer, 10:00, Assistant Professor Dempster.

23. Discharge through Gases, Ionising Processes, and the Nature of Gaseous Ions.—A lecture course or gaseous ionisation covening the fundamental facts of gaseous ionisation and the discharge through gases including the most recent advances in this field. The course will also include a brief discussion of the chemical and physical effects resulting from ionisation. Prerequisites: Physics 10, 13, and Calculus. Mj. Autumn, 1:30, Dr. Loeb.

Mathematics 27: Units and Dimensions.—The theory of units and dimensions as applied to the measurement of concrete magnitudes and the mathematical transcription of physical experiments. Physical similitude and the

interpretation of models. Numerical computations and the reduction of observations. Prerequisite: General Physics and some knowledge of Calculus. Mj. Summer, 10:00, Associate Professor Lunn.

28. Photographic Processes.—Lectures and laboratory work on the laws of photographic action. Effects of exposure and development on opacity and density; orthochromatism, plate grain, speed, intensification, reduction, and the applications of these to the photography of exceptional subjects. Prerequisite: Calculus. Mj. Assistant Professor Lemon. [Not given in 1921–22.]

III. GRADUATE COURSES

31, 32, 33. Theoretical Physics.—A series of lectures chiefly in Theoretical Physics, Hydrodynamics, Elasticity, Capillarity, Molecular Physics, Thermodynamics, Wave-Motion, Sound, Optical Theories, Electricity, and Magnetism. 4 hours a week. Prerequisite: Physics 10, 11, and 13 and Calculus. Mj. Autumn, Winter, and Spring, 11:00, Professor Michelson.

40, 41, 42, 43. Research Course.—This course is intended for graduate students who are prepared to undertake special research. Except in the case of a purely mathematical problem, the entire time is to be devoted to work in the laboratory. DMj. Autumn, Winter, and Spring, Professors Michelson, Millikan, Gale, Assistant Professors Lemon and Dempster.

***45. Aëronautics 1.**—A course of lectures accompanied by a few demonstration experiments on the mechanical principles of flight. Dynamic similitude, elementary aërodynamics of fluid resistance, and the classical theory of Rayleigh form the principal theoretical topics. Much time is given to the discussion of the experimental work of Eiffel and the National Physical Laboratory on flat and cambered aërofoils, lift and drift coefficients. The Phugoid theory of Lanchester, longitudinal lateral and directional stability are taken up, as well as the modern gyroscopic devices of control. Prerequisite: Calculus and Elementary Mechanics, or consent of instructor. Mj. Spring, Assistant Professor Lemon.

48. Spectrometry I.—Laboratory work in photographing and measuring the spectra of various elements. Use of the concave grating, echelon, and interferometer. Prerequisite: consent of the instructor. Mj. Winter, 2:30, Assistant Professor Lemon.

51. Thermodynamics.—Lectures upon the fundamental principles underlying the mechanical theory of heat and the application of these principles to physical and thermochemical problems. Prerequisite: two years of college Physics and Calculus. 5 hours a week. Mj. Spring, Professor Millikan.

52. Electron Theory I.—A course of graduate lectures covering the work of the last twenty years on the electrical properties of gases, the electron theory, and radioactivity. Prerequisite: same as for course 51. 5 hours a week. Mj. Professor Millikan. [Not given in 1921–22.]

53. Electron Theory II.—A continuation of 52, dealing with the application of the electron theory to metallic conduction, to the Seebeck, Peltier, Thomson, and Hall effects, to optical phenomena in magnetic fields, to the subject of electromagnetic mass, etc. 5 hours a week. Mj. Professor Millikan. [Not given in 1921–22.]

56. Quantum Theories and Theories of Atomic Structure.—A course of graduate lectures dealing with X-rays and the related phenomena, the study of which has thrown new light upon the structure of the atom and the relations of the atom and the molecule. Prerequisite: College Physics and Calculus. Mj. Summer, 9:00, Professor Millikan.

Mathematics 178, 179. Relativity and the Theory of Gravitation.—The first major will be devoted to the special or restricted principle of relativity of Einstein, its various applications to physical theory, and the mathematical form given it by Minkowski. The second major will be given to the Riemann geometry of curved hyperspace, four-dimensional vector analysis, and the

Einstein theory of the gravitational field. Prerequisite: Thorough preparation in Calculus and General Physics. Two consecutive majors, Autumn, Winter, Associate Professor Lunn.

Mathematics 51. Theory of Sound.—Dynamical theory of production; transmission and reception of sound. Analysis and synthesis of vibrations. Illustrations by acoustic apparatus and musical instruments. Analogies in electromagnetic oscillations. Mj. Winter, Associate Professor Lunn.

69. Physical Optics.—A theoretical treatment of optical phenomena in the realms of dispersion interference and diffraction. Mj. Summer, 10:00, Professor Gale.

75. Relativity, Electro-Magnetism, and Gravitation.—A course of graduate lectures for Physicists and advanced students on the most recent developments in theoretical Physics. Mj. Summer, 11:00, Professor Silberstein.

275. Physics Club.—This organization, consisting of all instructors and graduate and advanced students in the Department, meets on Thursday of each week from 4:30 to 6:00 for the discussion of recent research.

TABULAR VIEW OF COURSES OFFERED BY THE DEPARTMENT OF PHYSICS, 1921–22

Hour	Summer, 1921	Autumn, 1921
7:00	3S. Mechanics, Molecular Physics and Heat Mj. (States and McAllister) (7:00–9:00, 10:00–12:00, 1:30–3:30) 4S. Electricity, Sound, and Light Mj. (Knudsen and States) (7:00–9:00, 10:00–12:00, 1:30–3:30)	3. Mechanics Mj. (7:00–9:00, 9:00–11:00, 11:00–1:00, 1:30–3:30, 3:30–5:30, 7:00–9:00 P.M.) Lecture Mon. all sections, 4:30 P.M. (Lemon, Taylor, Knudsen)
8:00	9. Elementary Wireless Telegraphy Mj. (Kannenstine) (8:00–10:00)	4S. Electricity, Sound, and Light Mj. (Akeley and Monk) 8:00–10:00 and 12:30–2:30
9:00	7. Lecture Demonstration Course Mj. or M. either Term (Taylor) 56. Quantum Theories and Theories of Atomic Structure Mj. (Millikan)	1. Elementary Physics Mj. (Fischer and Harris) (9:00–11:00, 11:00–1:00, 1:30–3:30, 3:30–5:30, 7:00–9:00) 7. Lecture Demonstration Course Univ. Coll. and R. 32 (Alternate weeks) ½Mj. (Lemon) 11. The Kinetic Theory Mj. (Millikan)
10:00	17. Experimental Physics (Advanced) Light Mj. (10:00–12:00) Gale and Taylor) 22. Electrical Circuits Mj. or M. either Term (Dempster) Math. 27. Units and Dimensions (10:00) (Lunn) 69. Physical Optics (10:00) (Gale)	17. Experimental Physics (Advanced) Light Mj. (10:00–12:00) (Taylor) Math. 178. Relativity and Theory of Gravitation I (Lunn)
11:00	75. Relativity, Electro-magnetism, and Gravitation (Silberstein)	31. Theoretical Physics Mj. (Michelson)
1:30	1. Elementary Physics DM. 1st Term (Monk) (1:30–4:30) 2. Elementary Physics DM. 2d Term (Monk) (1:30–4:30) 20. Physical Manipulation M. 1st Term, Repeated 2d Term (1:20–3:30) (Loeb)	23. Discharge through Gases: Ionising Processes, and the Nature of Gaseous Ions Mj. (Loeb)
2:30	18. Experimental Physics (Advanced Electricity and Magnetism 1 Mj. (Kannenstine) (2:30–4:30)	21. Radioactivity and Discharge through Gases Mj. (Dempster) (2:30–4:30)
3:30		
		41. Research (Hours to be arranged)

TABULAR VIEW OF COURSES OFFERED BY THE DEPARTMENT OF PHYSICS, 1921–22—*Continued*

Hour	Winter, 1922	Spring, 1922
7:00	2. Elementary Physics Mj. (Fischer and Harris) (7:00–9:00, 9:00–11:00, 11:00–1:00, 1:30–3:30, 3:30–5:30, 7:00–9:00)	
8:00	3. Mechanics Mj. (States, Minton, Monk, McAllister) (8:00–10:00, 10:00–12:00, 12:30–2:30, 2:30–4:30) Wed. all sections, 4:30 P.M. 18. Experimental Physics (Advanced) Electricity and Magnetism I. Mj. (Kannenstine) (8:00–10:00)	3S. Mechanics, Molecular Physics and Heat Mj. (Fischer) (8:00–10:00) 15. Mechanics and Wave-Motion Mj. (Dempster) 4. Electricity (States, Minton, Monk, McAllister) (8:00–10:00, 10:00–12:00, 12:30–2:30, 2:30–4:30) Wed. all sections, 4:30 P.M.
9:00	4. Electricity Mj. (Taylor, Knudsen) (9:00–11:00, 11:00–1:00, 1:30–3:30, 3:30–5:30, 7:00–9:00) Mon. all sections, 4:30 P.M. 7. Lecture Demonstration Course ½Mj. (Lemon) Univ. Coll. and R. 32 Sat. (Alternate weeks) 12. Light Mj. (Loeb) Math. 51. Theory of Sound (Lunn)	5. Heat, Sound and Light Mj. (Taylor, Knudsen, ———) (9:00–11:00, 11:00–1:00, 1:30–3:30, 3:30–5:30, 7:00–9:00) Mon. all sections, 4:30 P.M. 7. Lecture Demonstration Course ½Mj. (Lemon) Univ. Coll. and R. 32 Sat. (Alternate weeks) 51. Thermodynamics Mj. (Millikan)
10:00	13. Electricity and Magnetism Mj. (Dempster) Math. 179. Relativity and Theory of Gravitation II (Lunn)	
11:00	32. Theoretical Physics Mj. (Michelson)	33. Theoretical Physics Mj. (Michelson)
2:30	48. Spectrometry I. Mj. (Lemon)	45. Aëronautics Mj. (Lemon) 16. Experimental Physics (Advanced) Molecular Physics and Heat (Millikan and Dempster) (2:30–4:30)
3:30		19. Experimental Physics (Advanced) Electricity and Magnetism II (3:30–5:30) Mj. (Kannenstine)
	42. Research Course (Hours to be arranged)	43. Research Course (Hours to be arranged)

THE DEPARTMENT OF CHEMISTRY

OFFICERS OF INSTRUCTION

JULIUS STIEGLITZ, PH.D., SC.D., CHEM.D., Professor and Chairman of the Department of Chemistry.
WILLIAM DRAPER HARKINS, PH.D., Professor of Chemistry.
HERMANN IRVING SCHLESINGER, PH.D., Associate Professor of Chemistry.
ETHEL MARY TERRY, PH.D., Assistant Professor of Chemistry.
JOHN WILLIAM EDWARD GLATTFELD, PH.D., Assistant Professor of Chemistry.
GERALD LOUIS WENDT, PH.D., Assistant Professor of Chemistry.
BEN H. NICOLET, PH.D., Assistant Professor of Organic Chemistry.
MARY MENDA RISING, PH.D., Instructor in Chemistry.
HOWARD ADLER, Ph.D., Instructor in Chemistry.
MORRIS KHARASCH, S.B., PH.D., National Research Fellow in Organic Chemistry.
CLARENCE E. IRION, S.B., Assistant Curator.
ZONJA WALLEN LAWRENCE, S.B., Associate in General Chemistry.
JOHN F. MCBRIDE, S.B., S.M., Research Instructor in Organic Chemistry.
ANSON HAYES, S.B., Research Associate in Physical Chemistry.
LILLIE EICHELBERGER, S.B., Research Associate in Organic Chemistry.
HERMAN B. SIEMS, S.B., Lecture Associate.
EVERETT BOWDEN, S.B., A.M., Assistant in Chemistry.
HENRY L. COX, S.B., S.M., Assistant in Chemistry.
MARIE FARNSWORTH, S.B., Assistant in Quantitative Analysis.
AARON FELDMAN, S.B., Assistant in Chemistry.
AUBREY C. GRUBB, A.B., S.M., Assistant in Qualitative Analysis.
SIMON HERZFELD, S.B., Assistant in Physical Chemistry.
ALFRED JURIST, S.B., Assistant in General Chemistry.
ROBERT STERN LANDAUER, S.B., Assistant in Quantitative Analysis.
KARL S. MEANS, S.B., Assistant in Organic Chemistry.
FRANK V. SANDER, S.B., Assistant in Organic Chemistry.
JAMES KIDDER STEWART, S.B., Assistant in Chemistry.
EDGAR WERTHEIM, S.B., Assistant in Organic Chemistry.
MARGARET WILLCOX, A.B., Assistant in Chemistry.

RAYMOND D. MULLINIX, Ph.D., Professor of Chemistry, Rockford College (Summer, 1921).
EDWARD W. WASHBURN, PH.D., Professor and Head of the Department of Ceramics, University of Illinois (Summer, 1921).
GERHARD DIETRICHSON, S.B., PH.D., Instructor in Physical Chemistry, University of Illinois (Summer, 1921.)

FELLOWS, 1921–22

SAMUEL KING ALLISON, S.B.
HENRY KELLY BUCKNER, A.B.
HERMAN BERNHARD SIEMS, S.B. (Swift Fellow)
JAMES KIDDER STEWART, S.M. (Loewenthal Fellow)
MARGARET FITCH WILLCOX, A.B. (Edith Barnard Fellow)
ROBERT STERN LANDAUER, Ph. D., (Du Pont Fellow)
JULIAN FRANCIS SMITH, S.M.

INSTRUCTIONAL WORK

The Department aims to prepare students (1) for government service, (2) to teach in colleges or universities, (3) to teach in secondary schools, (4) to fill positions as technical experts or assistants in chemical industries, (5) to become analysts in commercial and sanitary laboratories. The elementary courses may be taken with advantage by students having none of these ends in view.

Special stress will be placed on throughness of preparation and the symmetrical development of the student's knowledge. The object of the courses will be not so much to train specialists as to prepare the student to undertake intelligently all kinds of work of a chemical nature. Those intending to become practical chemists will find a thorough course of purely scientific chemistry the best basis for future specialization in any branch of the subject. Those who incline toward inorganic chemistry will be required to do much physical and a considerable amount of organic work; those proposing to become organic chemists will be required to do work in inorganic chemistry of a more advanced nature than that given in the elementary and analytical courses, and some physical chemistry, etc. The test of time and the experiences of the graduates of the Department have fully justified this form of training.

RESEARCH

Students are encouraged to begin research work as soon as their preparation justifies it. Facilities for research in all lines, whether of inorganic, organic, analytical, radioactive, or physical chemistry, are provided. Special opportunities to pursue entirely independent research work, as guests of the University (see p. 5), will be given to maturer students who have already obtained the Doctor's degree. Besides a number of general University Fellowships which are usually allowed to the Department for candidates for the Ph.D. degree, there are five specially endowed Fellowships in Chemistry with a return of from $120 to $920 per year (three quarters): the Swift Fellowship, endowed by Mrs. Gustavus F. Swift; the DuPont Fellowship, granted by the E. I. du Pont de Nemours Company; the Loewenthal Fellowship, a memorial to Joseph B. Loewenthal: the Hoskins Fellowship, donated by William Hoskins; and the Edith Barnard Fellowship, a memorial to Edith Ethel Barnard, a former instructor, donated by her friends and family.

SCHOLARSHIPS IN CHEMISTRY

Besides the regular University Scholarships (p. 8) which are available for graduate and undergraduate students in chemistry, there is a special scholarship in Chemistry, The Joseph B. Triner Scholarship, donated by Joseph B. Triner to be awarded to a Czecho-Slovak student entering the University for work in Chemistry.

ARRANGEMENT OF COURSES

1, 2, 3, 2S, 3S, General Chemistry, Inorganic; 4, Elementary Organic; 6, 7, 10, 38, Qualitative Analysis; 8, 9, 11–19, Quantitative Analysis; 20, Elementary Physical Chemistry; 24, Elementary Colloid Chemistry; 25, Toxicology; 26, Detection of Poisons; 30–49, Organic Chemistry; 50–59, Advanced Inorganic Chemistry; 60–74, Advanced Physical Chemistry; 75–79, Radio-Chemistry; 83, Teaching of Chemistry; 90–101, Research.

REQUIREMENTS FOR DEGREES

THE DEGREE OF DOCTOR OF PHILOSOPHY

I. *Chemistry the primary subject.*—When the degree of Doctor of Philosophy in Chemistry is desired, the branch of chemistry touched by the dissertation is offered as a *major* subject and some other branch of chemistry as the *first minor* subject. Besides this, a sufficient knowledge of other fundamental phases of the science is required as well as sufficient work in a *second minor* subject in some other department. These conditions are complied with when the following specific requirements are fulfilled:

1. The presentation of a dissertation embodying the result of original research in General, Inorganic, Analytical, Organic, Physico-organic, or Physical Chemistry, or Radioactivity. This must constitute a real contribution to knowledge, and the work is usually done under the direction of an officer of the Department.

2. The general requirements for all candidates, in advance of General Chemistry: courses 4,[1] 6–9, 11 (½Mj.), 20, and two majors selected from courses 10 or 13–19, 60, 61, 30–34, 38, 39.

3. In addition to the above, one of the following specific sets of requirements, arranged according to the thesis subject:

General Chemistry and Inorganic Chemistry: courses 60, 61, 35 (or 30 and 31), 50, 51 and 52 or 62 or 63, and one major taken from courses 13–19, 30–38, 47, 48, 52, 63; *Organic Chemistry:* courses 30–32, 35[2]–37, 50, 60 or 61 or 62, and one major from 10, 13–19, 38, 39, 47, 48, 51, 52, 55, 60, 61, 62; *Physico-organic Chemistry:* courses 30–32, 35, 60, 61, and one major from 36, 47, 48, 51, 62 or 63, and one major taken from courses 10, 13–19, 38, 39, 47, 48, 51, 52, and 63. *Physical Chemistry:* courses 60, 61, 62, 35 (or 30 and 31), 50, and 36 or 51 or 63, and one major taken from courses 10, 13–19, 30–32, 36–38, 47, 48, 52. *Radioactivity* or *Photo-Chemistry:* courses 60, 61, 62, 50, 63 or 76, and Physics 52 (Electron Theory), and one major taken from courses 10, 13–19, 22, 30–32, 35–38, 52 and 63. In addition to one set of these specific requirements at least six half-majors will be chosen from the special courses 38, 42–46, 47, 48, 55–58, 65–79. As a final test of preparation for research work a student as a rule will be asked to repeat without assistance some piece of published work, generally as a half-major included in course 37, 51 or 52, 63 or some similar course. The research work will require from four to six quarters.

4. Sufficient work of an advanced character in another department to make a *second minor* of *three majors*. The following are the requirements for such a minor in various departments: (*a*) In *Physics:* three of the courses 11, 12, 13, 16, 17, 18, 19, 48, 49, 51, 52, 53, 55 or 56; courses 3, 4, 5 are prerequisite to these. (*b*) In *Physiological Chemistry:* three majors selected from 19, 20, 24, 25, 37, 38, 39, or 42. (*c*) In *Geology:* courses 15, 16, and 52 or their equivalent. Courses 7 or 8, and 11, 12, 14 would be prerequisite to these courses. (*d*) In *Geography:* courses 17, 18, 21, and their prerequisite courses. (*e*) In *Hygiene and Bacteriology:* course 12 and two majors in course 15; courses 2 and 3 are prerequisite to these.

[1] Course 4 may be omitted by graduate students when advanced work in Organic Chemistry is taken.

[2] Course 35 will be omitted when courses 30–31 have included laboratory work.

With permission, course 10 or 11 may be substituted for course 12. (*f*) In *Home Economics* (Food Chemistry and Nutrition): 3 Majors selected from courses 36 to 42, or 50. (*g*) In *Physiological Chemistry* and *Food Chemistry:* any three courses listed under (*b*) and (*f*), but Physiological Chemistry 19 and Home Economics 36 must not *both* be offered, nor both Physiological Chemistry 20 and Home Economics 38A.

II. *Chemistry the secondary subject.*—When Chemistry is a secondary subject, the requirement is determined after conference with the Head of the Department in which the major work is done. Courses 6, 7, and 8, and five other majors in advance of 8, will be required when Chemistry is the only secondary subject; courses 6, 7, and 8, and two other majors, when Chemistry is one of two secondary subjects. Elementary Physical Chemistry or Organic Chemistry, according as the major subject belongs to the Physical or the Biological Group, is recommended. When Physics is the major subject and Chemistry the minor, five majors beyond course 8 will be required with emphasis on Quantitative Analysis and Organic Chemistry.

THE MASTER'S DEGREE

For the Master's degree in Chemistry a dissertation and eight majors of graduate work in Chemistry are required if all the work is in Chemistry. These majors must be selected from courses in advance of 9, with the approval of the Chairman of the Department. Courses prerequisite to these must be taken, but cannot be counted in reckoning the eight required majors. At least one course in Physical Chemistry and one in Organic Chemistry must be included in the courses taken if they have not been taken before.

Up to three chemistry courses given in the Departments of Physiological Chemistry, Geology, and Home Economics may be included in these eight majors.

The eighth major of graduate work will be devoted to specific preparation (in residence) for the dissertation, either in the laboratory (research) or in the library (historical work), under the direction of some instructor chosen by the candidate.

Courses leading to the doctorate and Master's degrees in the Chemistry of Nutrition are given in the Department of Home Economics in conjunction with other departments.

THE DEGREE OF BACHELOR OF SCIENCE

Chemistry may be taken as a major subject to fulfil the requirement for a principal sequence or as a minor subject to fulfil the requirement for a secondary sequence. Guidance as to a more through preparation in college for professional work in Chemistry is given below (p. 45).

I. PRINCIPAL SEQUENCES

1) Courses 2, 3 (or 2S, 3S), 4, (or 4S), 6, 7, 8, 9, 20, and any other course in the Department except 1.

2) Combination with other science departments[1]: By dropping the necessary majors from the latter portion of sequence 1) above, nine major sequences may be offered involving the following courses: (1) three majors in College

[1] Recommendation for appointment to teach Chemistry in a secondary school requires at least courses 2, 3 (or 2S, 3S), 4 (or 4S), 6, 7, 8, and 20. (See page 47.)

Physics, i.e., 3, 4, 5 (3S, 4S), but not 1, 2, preceding or accompanying six Chemistry courses enumerated in 1) above; (2) one to three majors in Geology selected from Geology 2, 3, 11, 12, 40–45, 50, 52, 53, when these courses follow Chemistry courses 2, 3 (or 2S, 3S), and 6; (3) two majors of Physiological Chemistry, provided they are taken after courses 2, 3 (2S, 3S), 4, (or 4S), and 6 in Chemistry; (4) two majors in Chemistry of Foods and Dietetics, provided these courses follow 2, 3 (2S, 3S), 4 (or 4S), and 6 in Chemistry.

II. SECONDARY SEQUENCES

a) For students specializing in Physics: courses 2, 3, 6, 7, 8, and either 4 (or 4S) or 9 or 20.

b) For students specializing in Biological Science: courses 2, 3, 4 (or 4S), 6, 7, and 8. In addition course 20 is recommended on account of the increasing application of physical chemistry in biological work.

c) For students specializing in Geology: courses 2, 3, 6, 7, 8, 9. The Department strongly advises courses 10, 14, and 20.

SPECIAL STUDENTS

Special or unclassified students, not candidates for a degree, will be received, but in every case they will be required to give evidence, satisfactory to the instructors, that their previous training has been sufficient to enable them to derive full profit from the courses they propose to take.

PREPARATION FOR PROFESSIONAL WORK

GRADUATE WORK

1. *Preparation for Teaching in University and College Positions:* (*a*) For recommendations for major appointments in the larger universities and colleges only students who have taken the degree of Doctor of Philosophy will be considered to have had an adequate preparation. For certain university positions marked ability in research evidenced in the work for the degree will be considered essential. An academic career of real promise demands as never before research ability and training, which should give a man the broader viewpoint for the past and the future of his science, as well as the enthusiasm for his subject as a living science, which are the earmarks of the inspiring teacher. (*b*) For recommendations for chairs in Chemistry in smaller colleges the preparation demanded for the Master's degree will for the present be considered sufficient.

2. *Preparation for Technical and Government Work:* Thorough scientific training in all branches of chemistry as required for the Doctor's degree forms the best preparation for a career as a chemical expert in any branch of chemical industry. With this preparation the principles and details of technical processes are quickly grasped, advances in industrial processes are intelligently followed, and newly discovered principles are readily applied. A broad preparation, including advanced work in physical chemistry and mathematics for the candidate specializing in organic or inorganic chemistry, and vice versa, is strongly recommended.

All the more important requests received from technical establishments specify a doctorate of philosophy, with its training to do research work as a fundamental requirement.

For the more important government positions in Chemistry the doctorate of philosophy is generally demanded as an essential condition for candidacy.

UNDERGRADUATE WORK

I. For the college student who wishes to use his work for the Bachelor's degree as an opportunity toward a thorough preparation for professional work in Chemistry, a careful and logical selection of his courses during the four years of his college work is invaluable in the interest of a broad and adequate preparation with a minimum of wasted effort. For the benefit of such a student the following outline of essential courses is given with an indication of the sequence in which these are best taken. Students taking this course will be given the preference, other qualifications being equal, in recommendations for appointments. for which they are fitted. (See II below).

A. *General Outline of College Work*

(1) *English*, 2 majors, required of all college students in their first year. (2) *Chemistry*, 15 to 18 majors, to be described below. The student should start in his first year (Autumn or Summer) with Chemistry 1 or, if he has had high-school Chemistry, with 2S. (Entrance Physics is a prerequisite, and Physics 1 and 2 should be taken in the student's first two quarters if he has not had high-school Physics.) (3) *Physics*, 2 or 3 majors. Physics 3, 4, and 5 or 3S and 4S for students who have had Trigonometry. This work should be taken in the student's first or second college year. (Entrance Physics is a prerequisite, and Physics 1 and 2 should be taken in the student's first two quarters if he has not had high-school Physics.) (4) *Mathematics*, 3 majors (at least). Courses 1, 2, 3 and 15 in Mathematics, covering college algebra, trigonometry, analytical geometry and elementary calculus, are recommended for the student's first or second year. Advanced work in Calculus is desirable. (5) *German*, 3 majors (or two years of high-school German). A knowledge of scientific German is greatly to be desired for advanced work in Chemistry. The student is advised to take the German in his *second* (not in his first year) or third college year, preferably as extra work. *French* may well be taken in the same way. (6) *Elective:* 7 to 11 majors, or more, if high-school work included Trigonometry German, Physics, and Chemistry.

B. *Sequence of Fundamental Courses in Chemistry*

(1) *General Inorganic Chemistry*, first year: 2S and 3S for students who have had high-school Chemistry, or 1, 2 and 3 for students who have not had admission Chemistry. On recommendation of the instructor, the laboratory work of course 3 or 3S may be omitted in the case of very able students and course 4 or 6 (major) taken simultaneously with the lectures (½Major) of course 3 or 3S. (2) *Qualitative Analysis*, 2 majors, Courses 6 and 7. (3) *Quantitative Analysis*, 3 majors. Courses 8, 9, and a major from courses 11–19. (4) *Organic Chemistry*, 3 to 3½ majors. Course 4 and courses 30 (½ major, lectures, Autumn), 31, and 32, or courses 4S, 34, and 32. (5) *Physical Chemistry* (third and fourth years), 2 to 3 majors, beginning with course 20. (6) *Elective*, 5 to 6 majors, to be taken in advanced courses in analytical chemistry (10–19) organic chemistry (35–88 and special lectures), inorganic chemistry (50–52 and special lectures), physical chemistry (60–63, and special courses), radioactivity, courses 75–79, physiological chemistry (physiological chemistry 19, 20), chemistry of nutrition 1, or bacteriology (1, 2, 3), with a view to specialization in one of these branches. Students

are advised to consult very freely and early in their course with a Departmental Adviser, whose name may be secured at the Dean's office or at the office of Kent Chemical Laboratory, Room 19.

II. 1. *Preparation for Teaching:* For recommendations for minor appointments in universities and colleges the work represented by the principal sequence of 9 majors in Chemistry required for the Bachelor's degree (see p. 44), supplemented by from three to eight majors of advanced work in Chemistry, as outlined above, will be considered an adequate preparation.

The work represented by the principal sequence of 9 majors in Chemistry (see p. 44), required for the Bachelor's degree, is at present considered preparation for teaching in secondary schools. Chemistry courses 2, 3 (or 2S, 3S), 4 (or 4S), 6, 7, 8 and 20 must be included in the sequence. Some work in the College of Education is recommended. Men will find it advisable to be prepared also to teach Physics, Mathematics, or Geology. Women will find it wiser to combine Chemistry with Home Economics, Physics, Physiography, Physiology, Botany, or Zoölogy.

2. *Preparation for Technological Work:* Students who have taken from ten to eighteen majors of work in the Department, as outlined above, are able to fill satisfactorily positions as assistants in technical and analytical laboratories and, after some practical experience, to advance to positions of independent responsibility. The complete training represented by the work for the Ph.D. degree is recommended, however, as the only wholly adequate preparation for all desiring to make a profession of chemistry.

3. *Preparation for Government work:* For minor positions (e.g., junior chemist in the United States service) the Bachelor's degree is considered sufficient. The principal sequence in Chemistry, required for the degree, should be supplemented by *advanced* work in two or three branches of Chemistry (Inorganic, Organic, Physical, Analytical). If possible, the full course outlined under A and B should be taken.

The Department does not pledge itself to secure positions for those who have carried out any one of the above-recommended sets of courses; but, as a matter of fact, competent students find suitable places quickly, and in the past the demand for chemists has far exceeded the supply, particularly in the case of the *more completely* trained graduates (Ph.D.'s).

CHEMICAL SOCIETIES

The Kent Chemical Society is a club of students open to all those who have had six majors of Chemistry. The Society meets bi-weekly to listen to papers by members and others.

The Graduate Chemical Club is an informal club of men graduate students in chemistry, meeting for social and scientific purposes.

The Kappa Mu Sigma is a graduate Sorority of faculty women and women working for graduate degrees in some field of Chemistry. Advanced undergraduate women of high standing are eligible to associate membership.

The Chicago Section of the American Chemical Society holds monthly meetings (except in summer) which the students of the University are welcome to attend. Membership in the Society is open to advanced students at special rates.

LABORATORY FEE

There is a laboratory fee of $6.00 per major for all courses involving laboratory work in the Department of Chemistry. A deposit of $5.00 for breakage is also required of each student.

COURSES OF INSTRUCTION

NOTE.—After course 9, the courses are arranged in groups according to subjects; courses 11–19 include courses in Analytical Chemistry, 20 Physical Chemistry, 21–29 in special subjects of a Senior College character, 30–49 in Organic Chemistry, 50–59 in Inorganic Chemistry, 60–79 in Physical Chemistry and Radioactivity; 80–89 are general in nature, and 90–101 are research courses. Nos. 30–36, 42–45, 50, 51, 55–59, 60–62, and 75–79 are open to, and suitable for, Senior College students.

I. PRIMARILY FOR THE JUNIOR COLLEGES

1. Elementary General Chemistry: Inorganic I.[1]—Prerequisite: preparatory Physics. DM. Summer, First Term. Classroom, 6 hours a week; laboratory, 12 hours a week, MRS. LAWRENCE. Mj. Autumn. Classroom, 3 hours a week; laboratory, 6 hours a week, ASSISTANT PROFESSOR TERRY.

2. General Chemistry: Inorganic II (continuation of course 1)[2].—Prerequisite: course 1. DM. Summer, Second Term, MRS. LAWRENCE. Mj. Winter, ASSISTANT PROFESSER TERRY.

NOTE.—Course 2, Winter Quarter, is a continuation of course 1, but may be entered by those having credit for admission Chemistry.

3. General Chemistry: Inorganic III (continuation of course 2).[2, 3] Prerequisite: course 2. Mj. Spring, ASSISTANT PROFESSOR TERRY.

NOTE.—Courses 1, 2, and 3 are consecutive courses. Separate credit is given for each, but students are advised not to take one course only. The aim of these courses is to give a definite idea of the fundamental principles of chemistry, and not to overburden the student with a mass of unconnected facts. The lectures will be experimental to a considerable extent. The courses are designed to meet the wants, not only of those who wish to go more deeply into chemistry, but of all who wish to study the science as part of a liberal education.

1 N. Elements of Chemistry.—Primarily for student nurses. Classroom work, 3 hours a week; laboratory work, 4 hours a week. M. First Term, Autumn, ASSOCIATE PROFESSOR SCHLESINGER; Spring, 1921, DR. RISING.

2S. General Inorganic Chemistry (first course).[1, 2]—For students who have had preparatory Chemistry. Prerequisite: preparatory Chemistry and preparatory Physics, one unit each. DM. Summer, First Term. Classroom, 6 hours a week; laboratory, 12 hours a week, ASSOCIATE PROFESSOR SCHLESINGER; Mj. Autumn. Classroom, 3 hours a week; laboratory, 6 hours a week, ASSOCIATE PROFESSOR SCHLESINGER AND MRS. LAWRENCE.

3S. General Chemistry: Inorganic (continuation of course 2S).[1, 2]—DM. Summer, Second Term, ASSOCIATE PROFESSOR SCHLESINGER; Mj. Winter, ASSOCIATE PROFESSOR SCHLESINGER AND MRS. LAWRENCE.

NOTE.—Whenever, in exceptional cases, the preparation of a student in 2 or 2S justifies it, Qualitative Analysis may be substituted for 3 or 3S.

4. Elementary Organic Chemistry.[2]—Prerequisite: course 3 or 3S. Classroom, 3 hours a week; laboratory, 6 hours a week. Mj. Autumn, ASSISTANT PROFESSOR NICOLET; Winter, DR. RISING; Spring, ASSISTANT PROFESSOR GLATTFELD.

4S. General Organic Chemistry.[2]—Prerequisite: course 3 or 3S. Classroom, 5 hours a week; laboratory, 12 hours a week; DM., First Term, Summer, ASSISTANT PROFESSOR GLATTFELD.

[1] Limited-credit course: After a student has credit for 18 majors but less than 27, these courses will be credited at one-half major each; after he has credit for 27 majors they will not be credited at all.

[2] The classroom parts of courses 1, 2, 3, 2S, 3S, 4, 4S, or 6, may be taken without payment of laboratory fees by graduate students who have had equivalent courses in Chemistry.

[3] Students who receive a sufficiently high grade in the classroom and laboratory work of course 2 or 2S may be excused from the laboratory work of course 3 or 3S. Such students take the lectures of 3 or 3S as a half major and are permitted to take course 4 or 6 simultaneously with the lectures of course 3 or 3S if they so desire.

6. Qualitative Analysis (introductory course).[1]—The lectures deal with the chemistry of the analytical reactions, and special attention is given to the development and application of the laws of equilibrium and of solutions. This course is, in an important sense, one in advanced General Chemistry. Classroom, 2 hours a week; laboratory 8 hours a week. Prerequisite: course 3 or 3S. Mj. Summer, Autumn and Winter, DR. ADLER; Spring, DR. RISING.

7. Qualitative Analysis (continuation of course 6).—Mj. or DM. Summer, DR. ADLER; Autumn and Spring, DR. RISING; Winter, DR. ADLER.

NOTE.—Courses 6, 7, and 10 form a continuous course, which may be begun in any quarter. The aim of courses 6, 7, and 10 will be to train the student to do intelligent analytical work, based on a knowledge of the scientific principles of the subject, and to apply and amplify his knowledge of General and Physical Chemistry.

II. PRIMARILY FOR THE SENIOR COLLEGES

8. Quantitative Analysis (introductory course).—Chiefly laboratory work in gravimetric and volumetric analysis. Laboratory, 8 or 16 hours a week; lecture, 1 hour. Prerequisite: course 7. (May be taken simultaneously with course 6 or 7. Medical students will be admitted to the course after having taken course 6.) Mj. or DM. Summer, Winter, and Spring, ASSISTANT PROFESSOR WENDT; Autumn, ASSISTANT PROFESSOR GLATTFELD.

8M. Quantitative Analysis.—A special course for premedical and medical students giving the elements of gravimetric and volumetric analysis. Prerequisite: course 6. Summer, Winter, and Spring, ½Mj. ASSISTANT PROFESSOR WENDT; Autumn, ½Mj. ASSISTANT PROFESSOR GLATTFELD.

9. Quantitative Analysis (continuation of course 8).—Laboratory, 10 or 20 hours a week. Mj. or DM. Summer, Winter, and Spring, ASSISTANT PROFESSOR WENDT; Autumn, ASSISTANT PROFESSOR GLATTFELD.

NOTE.—Courses 8 and 9 form a continuous course which may be begun in any quarter.

10. Advanced Qualitative Analysis (continuation of courses 6 and 7).—Prerequisite: courses 7 and 8. Mj. or DM. Laboratory, 10 or 20 hours a week. Summer and Winter, DR. ADLER; Spring, DR. RISING.

11. Theories and Methods of Quantitative Analysis.—½Mj. 2 lectures a week. Prerequisite: course 9. Summer and Winter, ASSISTANT PROFESSOR WENDT.

12–19.—Special Methods in Quantitative Analysis.—

12.	Standard Methods of Water Analysis	½Mj.
13.	Standard Methods of Food Analysis	½Mj. or Mj.
14.	Analysis of Iron, Steels, and Ferro-alloys	½Mj. or Mj.
15.	Organic Elementary Analysis	½Mj.
16.	Preparation and Analysis of Gases	½Mj.
17.	Electrolytic Analysis, Gravimetric	½Mj.
18.	Electrometric Titration	½Mj.
19.	Advanced Rock and Mineral Analysis	Mj.

Laboratory work, 10 hours a week per major. Prerequisite: course 9, but for students in Domestic Science and for medical students, course 8. Summer, ASSISTANT PROFESSOR WENDT.

12A. Advanced Quantitative Analysis.—The course includes gas and electrolytic analyses, electro-titrations and silicate analysis. Laboratory work, 10 hours a week. Prerequisite: course 9. Mj. or ½Mj. Winter and Spring, ASSISTANT PROFESSOR WENDT.

13A. Applied Quantitative Analysis.—The course includes analytical methods taken from water and food analysis, iron and steel and slag analysis. Laboratory work, 10 hours a week. Prerequisite, course 9. Mj. or ½Mj. Winter and Spring, ASSISTANT PROFESSOR WENDT.

[1] The classroom parts of courses 1, 2, 3, 2S, 3S, 4, 4S, or 6, may be taken without payment of laboratory fees by graduate students who have had equivalent courses in Chemistry.

13. Standard Methods of Food Analysis.—½Mj or Mj. Autumn, DR. RISING.

14. Analysis of Iron, Steels and Ferro-Alloys.—½Mj. or Mj. Autumn, DR. Adler.

16. Gas Analysis.—½Mj. Autumn, DR. Adler.

20. Elementary Physical Chemistry.—An introductory survey course in elementary physical chemistry. Lectures, 3 hours; laboratory work, 6 hours. Prerequisite: course 8. Mj. Summer, First Term, PROFESSOR HARKINS; Second Term, DR. DIETRICHSON; Spring (1921 and 1922) ASSOCIATE PROFESSOR SCHLESINGER.

24. Introduction to Colloid Chemistry.—An elementary treatment of the main features of colloid chemistry. Lectures, 2 hours a week; laboratory work, 7 hours a week. Prerequisite: Physics 4, Chemistry 8. Mj. Spring, ASSISTANT PROFESSOR TERRY.

NOTE.—The lectures may be taken as one-half major without laboratory work.

25. Toxicology.—½Mj. Autumn, PROFESSOR HAINES AND ASSISTANT.

26. Poisons and Their Detection.—A conference and laboratory course. M. Spring, Second Term, PROFESSOR HAINES.

III. PRIMARILY FOR THE GRADUATE SCHOOL

30. Organic Chemistry.—Lectures, 3 hours a week; laboratory, 6 hours a week. Prerequisite: Quantitative Analysis 8, and for undergradate students, Elementary Organic Chemistry (course 4, 4S or an equivalent). Mj. Autumn, PROFESSOR STIEGLITZ.

NOTE.—Undergraduates must have 18 majors of college credit before they are eligible for admission to course 30 or 31. Students who have had adequate laboratory work in Organic Chemistry are admitted to the lectures of courses 30, 31, 32, or 33, each one-half major, without payment of a laboratory fee.

31. Organic Chemistry (continuation of course 30).—Lectures, 3 hours a week; laboratory, 4 hours a week. Mj. Winter, PROFESSOR STIEGLITZ.

32. Organic Chemistry (continuation of course 31).—The aromatic series. Lectures, 2 hours a week; laboratory work, 6 hours a week. Prerequisite: course 31 (course 4 or 4S for medical and home economics students). Mj. Spring, PROFESSOR STIEGLITZ.

33. Organic Chemistry (Advanced).—Fatty and aromatic series. Lectures, 5 hours a week; laboratory, 9 hours a week. Prerequisite: course 4 or 4S, DM. Second Term, Summer, ASSISTANT PROFESSOR GLATTFELD.

35. Organic Preparations.—Laboratory work, 10 or 20 hours a week. Prerequisite: courses 7 and 9, and Organic Chemistry. Mj. or DM. Summer, ASSOCIATE PROFESSOR GLATTFELD; Mj. Autumn, Winter, and Spring, ASSISTANT PROFESSOR NICOLET.

36. Organic Preparations (continuation of course 35).—Prerequisite: course 35 or its equivalent and a reading knowledge of German or French. Mj. or DM. Summer, ASSISTANT PROFESSOR GLATTFELD; Mj. Autumn, Winter, and Spring, ASSISTANT PROFESSOR NICOLET.

37. Organic Preparations (continuation of course 36).—Mj. or DM. Summer, ASSISTANT PROFESSOR GLATTFELD; Mj. Autumn, Winter, and Spring, ASSISTANT PROFESSOR NICOLET.

NOTE.—Students who have taken the laboratory work of courses 30, 31, and 32, or 30, 31, and 33, will omit course 35 and go on with course 36.

38. Qualitative Organic Analysis.—Prerequisite: courses 4, or 4S, 32 or 33, and 35. Mj. Autumn, DR. KHARASCH.

39. Organic Elementary Analysis.—Laboratory Work, about 60 hours. M. either Term. Spring, ASSISTANT PROFESSOR GLATTFELD; Autumn, DR. RISING; Winter, ASSISTANT PROFESSOR NICOLET.

42. The Carbohydrates.—½Mj. ASSISTANT PROFESSOR GLATTFELD. [Not given in 1921–22.]

43. Organic Nitrogen Derivatives.—Amino acids: polypeptids; uric-acid series; pyridine group; alkaloids; synthetic drugs. Prerequisite: course 31. ½Mj. Spring, PROFESSOR STIEGLITZ.

44. Physical Chemistry Applied to Organic Problems.—Lectures, 2 hours a week. Prerequisite: courses 31 and 20, 21, or 22. ½Mj. PROFESSOR STIEGLITZ. ASSISTANT PROFESSOR TERRY. [Not given in 1921–22.]

45. Selected Topics of Organic Chemistry.—Application of the electron theory to organic compounds; tautomerism; stereoisomerism; electromerism; organic dyestuffs. Prerequisite: Organic Chemistry. PROFESSOR STIEGLITZ. [Not given in 1921–22.]

46. Special Topics of Organic Chemistry.—Prerequisite: Organic Chemistry. ½Mj. Winter, ASSISTANT PROFESSOR NICOLET.

47. Catalysis.—Preparation and use of newer (solid) catalysts and promoters for organic reactions. Prerequisite: courses 11, 32 or 33, 35. Laboratory work, 10 hours a week. Mj. Autumn, ASSISTANT PROFESSOR TERRY.

48. Electrolytic Processes of Organic Chemistry.—Lectures, 2 hours a week, laboratory, 7 hours a week. Prerequisite: courses 11, 32 or 33, 35. Mj. Winter; ASSISTANT PROFESSOR TERRY.

NOTE.—The lectures may be taken as a half-major without laboratory work and without payment of a laboratory fee.

50. Inorganic Preparations.—Laboratory work, 10 or 20 hours a week; classroom work, 2 hours a week. Prerequisite: course 9. Summer and Spring. ASSOCIATE PROFESSOR SCHLESINGER.

51. Inorganic Preparations (continuation of course 50).—Mj. or DM. Prerequisite: course 50 and a reading knowledge of German or French. Same schedule as course 50.

52. Inorganic Preparations (continuation of course 51).—Mj. or DM. Same schedule as course 50.

55A, B, C. Advanced Inorganic Chemistry.—A series of half-major lecture courses comprising a systematic course in advanced Inorganic Chemistry from the point of view of recent results and future problems. The groups of the periodical system will be studied critically, and such topics as temperature measurement, thermal analysis, transition points, alloys, will receive detailed treatment. Prerequisite: Elementary Organic Chemistry and Physical Chemistry 20. Course A, ½Mj., Summer, 1921; B, ½Mj., Winter, PROFESSOR SCHLESINGER.

57. The Periodic System and the Interrelations of the Elements.—Lectures, ½Mj. PROFESSOR HARKINS. [Not given in 1921–22.]

57A. The Structure of the Atom.—A non-mathematical course in the nucleus of the atom as related to atomic evolution, and on the arrangement of the planetary electrons as related to valence. PROFESSOR HARKINS. [Not given in 1921–22.]

57B, C. Chemical Phenomena and Radioactivity.—From the point of view of atomic structure. Lectures. Each ½Mj.. B, Autumn, C, Winter. PROFESSOR HARKINS.

58. The Constitution of Liquids and Solids: Surface Tension and Colloids.—Lectures. ½Mj. PROFESSOR HARKINS. [Not given in 1921–22.]

59A. The Phase Rule and Its Industrial Applications.—Lectures and Colloquium, four hours, Tu., 3:30 and 4:30, W., Th., 4:30. Prequisite: Elementary Physical Chemistry. M. Summer, First Term, PROFESSOR WASHBURN.

59B. The Theory of Physico-Chemical Measurements.—Methods of measurement, sources of error, design of apparatus, etc. Lectures, W., Th., 11:00. Prerequisite: Elementary Physical Chemistry. Summer, First Term, PROFESSOR WASHBURN.

60. Physical Chemistry.—Lectures, 3 hours; laboratory work, 6 hours. Prerequisite: Elementary Physical Chemistry 20 and the Elements of Calculus for undergraduate students; Quantitative Analysis and the Elements of Calculus for graduate students. Mj. Autumn, PROFESSOR HARKINS.

61. Physical Chemistry: Electrochemistry (continuation of course 60).—Hours as in 60. Prerequisite: course 60 or its equivalent and Physics 3 and 4. Lectures. Mj. Winter, PROFESSOR HARKINS.

62. Physical Chemistry: Applications of Thermodynamics and Kinetic Theory (continuation of course 61).—Lectures, 4 hours a week. Prerequisite: course 61 or its equivalent in Physics. Spring, PROFESSOR HARKINS.

63. Physico-chemical Measurements.—Introductory to Research. Laboratory work, 10 or 20 hours a week. Prerequisite: course 61 and Physics 5. DM. Second Term, Summer, DR. DIETRICHSON; Mj. Autumn, Winter, and Spring, PROFESSOR HARKINS.

64. Crystal Structure and Valence as Related to Atomic Structure.—Lectures. ½Mj. Winter, 1921. PROFESSOR HARKINS.

65A, B. Theories of Solutions.—Each ½Mj. PROFESSOR HARKINS. [Not given in 1921–22.]

68A, B, C, D. Chemical Thermodynamics and Kinetics.—½Mj. in each Quarter. Prerequisite: Physical Chemistry and Calculus. Course D, M. First Term, Summer, PROFESSOR HARKINS.

69. The Chemistry of Gas Reactions.—Prerequisite: Physical Chemistry and Calculus. ½Mj. PROFESSOR HARKINS. [Not given in 1921–22.]

75. Subatomic Phenomena and Radioactivity.—Lectures from the point of view of the subatomic action of radiation and other forces. Prerequisite: course 20. ½Mj. Spring, ASSISTANT PROFESSOR WENDT.

76. Laboratory Course in Radioactivity.—To accompany or follow course 75. ½Mj. Spring, ASSISTANT PROFESSOR WENDT.

79. Chemical Effects of Gaseous Ionization.—Prerequisite: course 20 and Physics 52. Lectures 2 hours a week. ½Mj. ASSISTANT PROFESSSOR WENDT. [Not given in 1921–22.]

82. Club Meetings.—Meetings of the Kent Chemical Society will be held twice a month. They may be attended by anyone interested. The subjects for the meetings will be announced at least one week in advance. Summer, Autumn, Winter, and Spring.

85. The Chemistry and Preparation of Medicinal Drugs.—½Mj. Spring, PROFESSOR HAINES.

90–96. Research Work (for the Ph.D. Degree).—These courses will include from 30 to 40 hours a week of laboratory work, under the special direction of some one of the instructors in the Department. It is expected that research work for a Doctor's dissertation will require 4–6 quarters (4–6 DMjs.). Before being admitted to research a candidate must satisfy the instructors of the Department that his previous training has been sufficient.

90. Research in Organic and Physico-Organic Chemistry.—Mj. or DMj. Autumn, Winter, and Spring, PROFESSOR STIEGLITZ.

91. Research in Physical Chemistry and Radioactivity.—Mj., DM., or DMj. First Term, Summer, Autumn, Winter, and Spring, PROFESSOR HARKINS.

92. Research in Inorganic and Physical Chemistry.—Mj. or DMj. Summer, Autumn, Winter and Spring, ASSOCIATE PROFESSOR SCHLESINGER.

93. Research in Physico-Organic Chemistry.—Mj. or DMj. Autumn, Winter, and Spring, ASSISTANT PROFESSOR TERRY.

94. Research in Organic Chemistry.—Mj. Summer, Autumn, and Spring, ASSISTANT PROFESSOR GLATTFELD.

95. Research in Radioactivity and Photo-Chemistry.—Mj. or DMj. Summer, Winter, and Spring, ASSISTANT PROFESSOR WENDT.

96. Research in Organic Chemistry.—Mj. or DMj. Autumn, Winter, and Spring, Assistant Professor Nicolet.

97. Independent Research.—Mj. Summer, Autumn, Winter, and Spring.

98A. Master's Dissertation in Inorganic and Physical Chemistry.—Mj. Summer, Autumn, Winter, and Spring, Professor Schlesinger.

98B. Master's Dissertation in General Chemistry.—Mj. Autumn, Winter and Spring, Assistant Professor Terry.

98C. Master's Dissertation in Organic Chemistry.—Mj. Summer, Autumn, and Spring, Assistant Professor Glattfeld.

98D. Master's Dissertation in Quantitative Analysis.—Mj. Summer, Winter, and Spring, Assistant Professor Wendt.

98E. Master's Dissertation in Organic Chemistry.—Autumn, Winter, and Spring, Assistant Professor Nicolet.

98F. Master's Dissertation in Qualitative Analysis and Organic Chemistry.—Mj. Autumn, Winter, and Spring, Dr. Rising.

101. Research in the Chemistry of Food.—Mj. Summer, Autumn, and Spring, Associate Professor Blunt (Department of Home Economics).

CHEMISTRY COURSES IN THE DEPARTMENT OF PHYSIOLOGICAL CHEMISTRY

(See the Biological Group *Circular*)

CHEMISTRY COURSES IN THE DEPARTMENT OF GEOLOGY

50. Non-Metallic Mineral Deposits (except petroleum, natural gas, and asphalt).—A critical study of the nature, mode of occurrence, distribution, origin, treatment, and uses of the more important non-metallic deposits of economic importance, including coal. Several trips on Saturdays to mines, quarries, and plants in the vicinity. Prerequisite: Geology 2, 3, 5, a working knowledge of Chemistry, and 24 majors. Mj. Alternate Springs, Professor Bastin. [Not given in 1921–22.]

52. Genesis of Ore Deposits.—A study of the principles involved in the formation of ore deposits, and of the characteristic features of deposits formed under the wide variety of natural conditions. Individual mining districts will receive only incidental consideration as exemplifying the principles developed. Prerequisite: Geology 12, 16, and 40, and Chemistry 6. Mj. Winter, Professor Bastin.

53. Economic Geology of Metalliferous Deposits.—Deposits of the important metals will be studied seriatim with reference to the conditions under which they were formed and the geologic factors influencing their exploitation. Reports will be required summarizing the economic geology of certain mining districts. Practice will be given in the use of mine maps and the compilation of geologic cross-sections through mines. Prerequisite: Geology 52. Mj. Spring, Professor Bastin.

54. Field Work in Mining and Mining Geology.—Students in Mining Geology are advised to spend some of their summers in mining camps where they may find employment as miners, mine samplers, assayers, draughtsmen, surveyors, etc. For the sake of experience it is desirable that they serve in as many different capacities as practicable. In many mining camps opportunity is offered for a study of General Geology, ore deposits, mining machinery, metallurgical works, etc. Frequent communication with the instructor is required, and when the work and reports are sufficiently thorough, credit will be given. Prerequisite: courses 40 and 52. Summer, Professor Bastin.

CHEMISTRY COURSES IN THE DEPARTMENT OF HOME ECONOMICS

36. Chemistry of Food.—Study of the chemistry of fats, carbohydrates, proteins, as food constituents, with special emphasis upon the composition and nutritive value of such foods as meat, flour, milk, butter, etc. The laboratory

work is partly qualitative and partly quantitative. Prerequisite: Organic Chemistry. Laboratory fee, $6.00. Mj. Summer, Autumn, and Winter, Associate Professor Blunt, Assistant Professor Halliday.

37. Chemistry of Food (continued).—A continuation of the work in course 36. The subject-matter may be adapted to the special needs of the students. Lecture and laboratory. For graduate or Senior College students. Prerequisite: Home Economics 36 or its equivalent. Laboratory fee, $6.00. Mj. Spring, Assistant Professor Halliday.

38A. Nutrition.—A study of the processes of digestion and metabolism, and the nutritive requirements of the body, giving a scientific basis for the work in dietaries. The laboratory work consists chiefly of experiments on digestion and of qualitative and quantitative urine analysis in connection with special diets. Students may follow this course by either 39A or 38B, or both. Prerequisite: Home Economics 36. Laboratory fee, $3.00. M. Summer, First and Second Terms; Autumn, Spring, First Term, Associate Professor Blunt.

38B. Nutrition (continued).—A continuation of 38A. The course may include some study of pathological conditions in metabolism and a feeding or metabolism experiment. Laboratory fee, $3.00. M. Autumn, Spring, Second Term, Associate Professor Blunt.

39. Dietaries.—A study of the food requirements of individuals as modified by age, sex, activity, etc., with special consideration given to the food of school children and institutional groups. The theory of infant feeding is included. Prerequisite: Home Economics 3 or 5 and 38A. Laboratory fee, $3.00. M. Summer; Mj. Spring, Assistant Professor Roberts.

40. Readings in Nutrition.—Reading and discussion of some of the recent work on normal and abnormal nutrition. Prerequisite: Home Economics 38A and 39A or their equivalent. Mj. Summer, Spring, Associate Professor Blunt.

153. Advanced Textiles.—Methods used in the physical and chemical examination of textiles and their commercial significance. Prerequisite General Chemistry and Home Economics 152, or at least 4 majors of Chemistry. M. Summer, First Term, Assistant Professor O'Brien. Mj. Winter, Miss ———.

OUTLINE OF COURSES OFFERED BY THE DEPARTMENT OF CHEMISTRY, 1921–22

PART I.—Courses required for the principal sequence in chemistry and courses continued through the year. For laboratory courses and advanced lecture courses see Part II. Junior College courses are marked *.

Hour	Summer	Autumn	Winter	Spring
8:00	*4S. Elementary Organic Chemistry DM. 1st Term 5 lectures weekly Lab.: M., Tu., W., Th. 1:30–4:30 33. Organic Chemistry (advanced) DM. 2d Term Hours as for 4S. 11. Theories and Methods of Quantitative Analysis ½Mj. 2 lectures weekly (Hour subject to change)	*2S. General Inorganic Chemistry I Mj. Lect.:[1] M., Tu., W. Lab.: *a* Tu., W. 9:00–10:00; Th., F. 8:00–10:00 *b* Th., F. 8:00–11:00 (*a* and *b* together limited to 100) *c* W., Th., F. 1:30–3:30 (limited to 50) *d* Th., F., 1:30–4:30 (together with *c* limited to 100) *4. Elementary Organic Chemistry Mj. Lect.:[1] W., Th., F. Lab.: *a* M., Tu., Sat., 8:00–10:00 *b* M., Tu., 8:00–11:00 *c* M., Tu., 1:30–4:30 (*a*, *b* and *c* together limited to 100) *7. Qualitative Analysis II Mj. Lect.:[1] Tu., F. Lab.: 8 hrs. per week	*3S. General Inorganic Chemistry II Mj. Schedule as for 2S, Autumn Q. *7. Qualitative Analysis II Mj. Schedule as for Autumn Q. 11. Theories and Methods of Quantitative Analysis ½Mj. 2 lectures weekly 4. Elementary Organic Chemistry Mj. Hours as in Autumn Q. Limit as in Autumn Q.	*4. Elementary Organic Chemistry Mj. Lect.: M., Tu., W. Lab.: *a* Th., F., Sat., 8:00–10:00 *b* Th., F., 8:00–11:00 *c* Th., F., 1:30–4:30 *d* W., Th., F., 1:30–3:30 (Limit of 100 for all sections together) *7. Qualitative Analysis II Mj. Schedule as for Autumn Q.
9:00				20. Elementary Physical Chemistry Mj. Lect.: W., Th., F. Lab.: M., Tu., 9:00–12:00 or 1:30–4:30

NOTE.—Laboratory sections in courses 1, 2, 3, 2S, 3S, 4 for which at least 20 students are not registered will be withdrawn.

[1] For additional lectures at the regular period during the first or second week of the quarter, see the Quarterly Time Schedules.

OUTLINE OF COURSES OFFERED BY THE DEPARTMENT OF CHEMISTRY, 1921–22.—*Continued.*

	Summer	Autumn	Winter	Spring
10:00				*1N. Chemistry (Primarily for Student Nurses) M. 1st Term Lect.: M., Tu., W. Lab.: Tu., F., 9:00–11:00 (This course may be withdrawn)
11:00	*1. Elementary General Chemistry I. DM. 1st Term 5 lectures weekly Lab.: M., Tu., W., Th. 1:30–4:30 *2. Elementary General Chemistry II DM. 2d Term Hours as for 1. 20. Elementary Physical Chemistry Mj. Lect.: W., Th., F. Lab.: M., Tu. 9:00–12:00 or 1:30–4:30	*1. Elementary General Chemistry I Mj. Lect.: W., Th., F. Lab.: *a* M., Tu., 10:00–12:00; W., Th., 10:00–11:00 *b* M., Tu., 9:00–12:00 (*a* and *b* together limited to 50) *c* M., Tu., W., 1:30–3:30 (limited to 50) *d* M., T., 1:30–4:30 (*c* and *d* together limited to 75) 60.[2] Physical Chemistry I Mj. Lect.: W., Th., F. Lab.: Th., F., 1:30–4:30 or M., Tu., 9:00–12:00	*2. Elementary General Chemistry II Mj. Hours as for 1, Autumn Q. (Limit for sections *a* and *b*, 100, for *c*, 50, and for *c* and *d*, 100) 61.[2] Physical Chemistry II Mj. Schedule as for 60, Autumn Q.	*3. Elementary General Chemistry III Mj. Hours for 1, Autumn Q. (No limits) 62.[2] Physical Chemistry 3 Mj. 4 lectures per week
1:30	*2S. General Inorganic Chemistry I DM. 1st Term 5 lectures weekly Lab.: M., Tu., W., Th. 9:00–12:00 *3S. General Inorganic Chemistry II DM. 2d Term Hours as for 2S. *6. Qualitative Analysis I Mj. Lect.:[1] M., Th. Lab.: 8 hrs. weekly *7. Qualitative Analysis II Mj. Lect.: Tu., F. Lab.: 8 hrs. weekly	*6. Qualitative Analysis I Mj. Lect.:[1] M., Th. Lab.: 8 hrs. weekly	*6. Qualitative Analysis I Mj. Hours as for Autumn Q.[1]	*6. Qualitative Analysis I Mj. Hours as for Autumn Q.[1]

[1] For additional lectures at the regular period in the first or second week of the quarter, see the Quarterly Time Schedule.

[2] Primarily for graduate students. Undergraduates are permitted to enter.

OUTLINE OF COURSES OFFERED BY THE DEPARTMENT OF CHEMISTRY, 1921–22—*Continued.*

	Summer	Autumn	Winter	Spring
2:30	8. Quantitative Analysis I Mj. or DM. Lect.:[1] Th. Lab. 8 hrs. weekly[2] 8M. Quantitative Analysis (primarily for Medical Students) ½Mj. or M. Lect.:[1] Th. Lab.:[2] 4 hrs. weekly 9. Quantitative Analysis II. Mj. or DM. Lect.:[1] Tu. Lab.:[2] 8 hrs. weekly	8. Quantitative Analysis I Mj. See Summer Q. for hours 8M. Quantitative Analysis (primarily for Medical Students.) ½Mj. See Summer Q. for hours 9. Quantitative Analysis II Mj. Hours as for Summer Q.		8. Quantitative Analysis II Mj. Hours as in Summer Q. 8M. Quantitative Analysis (primarily for Medical Students) ½Mj. Hours as in Summer Q. 9. Quantitative Analysis II Mj. Hours as in Summer Q.
3:30			8. Quantitative Analysis I Mj. Lect.:[1] Th., at 3:30 Lab.:[2] 8 hrs. weekly 8M. Quantitative Analysis for Medical Students ½Mj. Lect.:[1] Th., at 3:30 Lab.:[2] 8 hrs. weekly 9. Quantitative Analysis II Mj. Lect.:[1] Tu. at 3:30 Lab.:[2] 8 hrs. weekly	
4:30		30.[3] Organic Chemistry. Mj. Lect.: M., Tu., W. Lab.: Th., F., 8:00–11:00 or 1:30–4:30	31.[3] Organic Chemistry Mj. Lect.: Tu., W. Lab.: Th., F., P.M. 2 hrs. each day	32.[3] Organic Chemistry Mj. Lect.: Tu., W. Lab.: Th., F., 2:30–5:30

[1] For additional lectures at the regular period during the first or second week of the quarter, see the Quarterly Time Schedule.

[2] For consultation hours for laboratory work see Quarterly Time Schedules.

[3] Primarily for graduate students. Undergraduates are permitted to enter.

OUTLINE OF COURSES OFFERED BY THE DEPARTMENT OF CHEMISTRY, 1921–22.

PART II.—More Advanced lecture and laboratory courses. For the hours for these courses the quarterly time schedules are to be consulted. Senior College Courses are marked †. Others are primarily for graduate students.

Summer	Autumn	Winter	Spring
†10. Advanced Qualitative Analysis Mj. or DM. Lab.: 10 or 20 hrs. per week	†13,14,16. Special Methods in Quantitative Analysis ½Mj., Mj. For details see departmental circular	†10. Advanced Qualitative Analysis Mj. Lab.: 10 hrs. a week	†10. Advanced Qualitative Analysis Mj. Lab.: 10 hrs. a week
†12–19. Special Methods in Quantitative Analysis ½Mj., or M., or DM. Lab. courses. For details, see departmental circular	35,[1] 36, 37. Organic Preparations Each Mj. Lab.: 10 hrs. a week	†12A. Advanced Quantitative Analysis ½Mj., or Mj. †12B. Applied Quantitative Analysis ½Mj., or Mj. For details see departmental circular	†12A. Advanced Quantitative Analysis ½Mj., or Mj. †12B. Applied Quantitative Analyses ½Mj., or Mj. See departmental circular for details
35,[1] 36, 37. Organic Preparations. Each Mj. or DM. Lab.: 10 or 20 hrs. a week	38. Qualitative Organic Analysis Mj. Lect. 2 hrs. and lab. 8 hrs. a week	35,[1] 36, 37. Organic Preparations Each Mj. Lab.: 10 hrs. a week	35,[1] 36, 37. Organic Preparations Each Mj. Lab.: 10 hrs. a week
50,[1] 51, 52. Inorganic Preparations Each Mj. or DM. Lab.: 10 hrs. a week	†39. Organic Elementary Analysis ½Mj. Lab. 60 hrs.	†39. Organic Elementary Analysis ½Mj. Lab. 60 hrs.	†39. Organic Elementary Analysis ½Mj. Lab. 60 hrs.
55B. Advanced Inorganic Chemistry ½Mj. 2 lect. a week	47. Catalysis. Preparation and Use of Newer Catalysts, etc. for Organic Reactions Mj. Lab.: 10 hrs. a week	46. Special Topics of Organic Chemistry ½Mj. 2 lect. a week	43. Organic Nitrogen Derivatives ½Mj. Lect.: 2 hrs. a week
61. Electrochemistry DM. 2d Term 5 lect. and 12 hrs. lab. a week	57B. Chemical Phenomena and Radio-activity from the Point of View of Atomic Structure ½Mj. 2 lect. a week	48. Electrolytic Processes of Organic Chemistry Mj. Lect. 2 hrs. and lab. 7 hrs. a week	50,[1] 51, 52. Inorganic Preparations Each Mj. Lab.: 10 hrs. a week
63. Physicochemical Measurements DM. 2d Term Lab.: 20 hrs. a week	63. Physicochemical Measurements Mj. Lab.: 10 hrs. a week	55A. Advanced Inorganic Chemistry ½Mj. 2 lect. a week	63. Physicochemical Measurements Mj. Lab.: 10 hrs. a week
68D. Kinetics in Chemical Reactions M. 1st Term 3 lect. a week	90–98. Research	57C. Chemical Phenomena and Radio Activity from the Point of View of Atomic Structure (cont.) ½Mj. 2 lect. a week	75. Subatomic Phenomena and Radioactivity ½Mj. 2 lectures a week
91–98. Research		63. Physicochemical Measurements Mj. Lab.: 10 hrs. a week	76. Laboratory Course in Radioactivity ½Mj.
		90–98. Research.	90–98. Research

[1] Informal class meetings accompany the laboratory work.

DOCTORS OF PHILSOSOPHY OF THE UNIVERSITY OF CHICAGO

MATHEMATICS

1896 Leonard Eugene Dickson, Professor of Mathematics, University of Chicago, Chicago, Ill.
The Analytic Representation of Substitutions on a Power of a Prime Number of Letters with a Dicsussion of the Linear Group.

John Irwin Hutchinson, Professor of Mathematics, Cornell University, Ithaca, N.Y.
On the Reduction of Hyperelliptic Functions ($p=2$) to Elliptic Functions by a Transformation of the Second Degree.

1898 Herbert Ellsworth Slaught, Professor of Mathematics, University of Chicago, Chicago, Ill.
The Cross-Ratio Group of 120 Quadratic Cremona Transformations of the Plane.

1899 John Anthony Miller, Professor of Mathematics and Astronomy, Swarthmore College, Swarthmore, Pa.
Concerning Certain Elliptic Modular Functions of Square Rank.

1900 Gilbert Ames Bliss, Professor of Mathematics, University of Chicago, Chicago, Ill.
The Geodesic Lines on the Anchor Ring.

George Lincoln Brown, Professor of Mathematics, South Dakota Agricultural College, Brookings, S.D.
A Ternary Linear Substitution Group of Order 3.360.

William Gillespie, Professor of Mathematics, Princeton University, Princeton, N.J.
On the Reduction of Hyperelliptic Intergrals ($p=3$) to Elliptic Integrals by Transformation of the Second and Third Degree.

Derrick Norman Lehmer, Associate Professor of Mathematics, University of California, Berkeley, Cal.
Asymptotic Evaluation of Totient Sums.

John Hector McDonald, Assistant Professor of Mathematics, University of California, Berkeley, Cal.
On the System of a Binary Cubic and Quadratic and the Reduction of Hyperelliptic Integrals of Genus Two to Elliptic Integrals by a Transformation of the Fourth Order.

Ernest Brown Skinner, Professor of Mathematics, University of Wisconsin, Madison Wis.
Ternary Monomial Substitution Groups of Finite Order with Determinant ± 1.

1901 William Findlay, Professor of Mathematics, McMaster University, Toronto, Ont.
The Sylow Subgroups of the Symmetric Group.

Thomas Milton Putnam, Professor of Mathematics and Dean of the Lower Division, University of California, Berkeley, Cal.
The Quaternary Linear Homogeneous Group and the Ternary Linear Fractional Group.

1903 Oswald Veblen, Professor of Mathematics, Princeton University, Princeton, N.J.; Major, Ordnance Department.
A System of Axioms for Geometry.

1904 William Henery Bussey, Professor of Mathematics and Dean in the College of Science, University of Minnesota, Minneapolis, Minn.
Generational Relations for the Abstract Group Simply Isomorphic with the Group LF(2; p^n).

Herbert Edwin Jordan, Assistant Professor of Mathematics, University of Kansas, Lawrence, Kan.
Group Characters of Various Linear Groups.

Arthur Whipple Smith, Professor of Mathematics and Head of the Department, Colgate University, Hamilton, N.Y.
Symbolic Treatment of Differential Geometry.

1905 Thomas Emory McKinney, Professor of Mathametics and Astronomy, University of South Dakota, Vermilion, S.D.
Concerning a Certain Type of Continued Fractions Depending on a Variable Parameter.

Robert Lee Moore, Associate Professor of Mathematics, University of Texas, Austin, Texas.
Sets of Metrical Hypotheses for Geometry.

1906 William Raymond Longley, Professor of Mathematics, Yale University, New Haven, Conn.
A Class of Periodic Orbits of an Infinitesimal Body Subject to the Attraction of n Finite Bodies.

Arthur Ranum, Assistant Professor of Mathematics, Cornell University, Ithaca, N.Y.
The Group of Classes of Congruent Matrices with Application to the Group of Ismorphisms of Any Abelian Group.

Anthony Lispenard Underhill, Associate Professor of Mathematics, University of Minnesota, Minneapolis, Minn.; Captain, Coast Artillery, in France.
Invariants under Point Transformations in the Calculus of Variations.

Buzz M. Walker, Professor of Mathematics, Dean of School of Engineering, Vice-President Mississippi Agricultural and Mechanical College, Agricultural College, Miss.
On the Resolution of Higher Singularities of Algebraic Curves into Ordinary Double Points.

1907 George David Birkhoff, Professor of Mathematics, Harvard University, Cambridge, Mass.
Asymptotic Properties of Certain Ordinary Differential Equations, with Applications to Boundary Value and Expansion Problems.

Robert Lacy Börger, Professor of Mathematics, Ohio University, Athens, Ohio.
On the Determination of Ternary Linear Groups in the Galois Field of Order p^2.

Louis Ingold, Assistant Professor of Mathematics, University of Missouri, Columbia, Mo.
Vector Interpretation of Symbolic Parameters.

Nels Johann Lennes, Professor of Mathemetics, University of Montana, Missoula, Mont.
Curves in Non-metrical Analysis Situs with an Application in the Calculus of Variations.

Frederick William Owens, Assistant Professor of Mathematics, Cornell University, Ithaca, N.Y.
The Introduction of Ideal Elements and Construction of Projective n-space in Terms of a Planar System of Points.

Norman Richard Wilson, Professor of Mathematics, University of Manitoba, Winnipeg, Canada.
Isoperimetrical Problems Which Are Reducible to Non-isoperimetrical Problems.

1908 Mary Emily Sinclair, Associate Professor of Mathematics, Oberlin, College, Oberlin, Ohio.
On a Compound Discontinuous Solution Connected with the Surface of Revolution of Minimum Area.

1909 Thomas Buck, Assistant Professor of Mathematics, University of California, Berkeley, Cal.
Oscillating Satellites near the Lagrangian Equilateral Triangular Points.

Arnold Dresden, Assistant Professor of Mathematics, University of Wisconsin, Madison, Wis.
The Second Derivatives of the Extremal-Integral.

Harris Franklin MacNeish, Assistant Professor of Mathematics, College of the City of New York, New York, N.Y.
Linear Polars of the k-hedron in n-space.

1910 Richard Philip Baker, Assistant Professor of Mathematics, State University of Iowa, Iowa City, Iowa.
The Problem of the Angle-Bisectors.

William Hunt Bates, Associate Professor of Mathematics, Purdue University, Lafayette, Ind.
An Application of Symbolic Methods of the Treatment of Mean Curvatures in Hyper-Space.

Theophil Henry Hildebrant, Associate Professor of Mathematics, University of Michigan, Ann Arbor, Mich.
A Contributition to the Foundations of Fréchet's Calcul Fonctionnel.

Egbert J. Miles, Assistant Professor of Mathematics, Yale University, New Haven, Conn.
The Absolute Minimum of a Definite Integral in a Special Field.

Anna Johnson Pell, Associate Professor of Mathematics, Bryn Mawr College, Bryn Mawr, Pa.
I. Biorthogonal Systems of Functions. II. Application to the Theory of Integral Equations.

Arthur Dunn Pitcher, Professor of Mathematics, Western Reserve University, Cleveland, Ohio.
The Interrelation of Eight Fundamental Properties of Classes of Functions.

Marion Ballantyne White, Professor of Mathematics, Carleton College, Northfield, Minn.
The Dependence of the Focal Point on Curvature in Space Problems of the Calculus of Variations.

1911 Lloyd Lyne Dines, Professor of Mathematics, University of Saskatchewan, Saskatoon, Canada.
The Highest Common Factor of a System of Polynomials, with an Application to Implicit Functions.

Theodore Lindquist, Professor of Mathematics, State Normal School, Emporia, Kan.
Mathematics for Freshman Students of Engineering.

Ralph Eugene Root, Professor of Mathematics, U.S. Naval Academy, Annapolis, Md.
Interated Limits in General Analysis.

Albert Harris Wilson, Associate Professor of Mathematics, Haverford College, Haverford, Pa.
The Canonical Types of Nets of Quadratic Forms in the Galois Field of Order p^n.

1912 Edward Wilson Chittenden, Assistant Professor of Mathematics, State University of Iowa, Iowa City, Iowa.
Infinite Developments and the Composition Property $(K_{12}B_1)_*$ in General Analysis.

1912 Charles Albert Fischer, Professor of Mathematics and Astronomy, Trinity College, Hartford, Conn.
Some Contributions to the Theory of Functions of Lines.

Charles Thompson Sullivan, Assistant Professor of Mathematics, McGill University, Montreal, Canada.
Properties of Surfaces Whose Asymptotic Lines Belong to Linear Complexes.

1913 William Charles Krathwohl, Associate Professor of Mathematics, Armour Institute of Technology, Chicago, Ill.
Modular Invariants of Two Pairs of Cogredient Variables.

Wilson Lee Miser, Assistant Professor of Mathematics, Armour Institute, Chicago, Ill.
On Linear Homogeneous Differential Equations with Elliptic Function Coefficients.

Frank Marion Morrison, Greenville, Ohio; Sometime Associate Professor of Mathematics, University of Washington, Seattle, Wash.
On the Relation between Some Important Notions of Projective and Metrical Differential Geometry.

Elton James Moulton, Associate Professor of Mathematics, Northwestern University, Evanston, Ill.
On Figures of Equilibrium of a Rotating Heterogeneous Fluid Body.

†Mildred Leonora Sanderson. Late Instructor in Mathematics, University of Wisconsin.
Formal Modular Invariants with an Application to Binary Modular Covariants.

1914 Myer Grupp Gaba, Assistant Professor of Mathematics, University of Nebraska, Lincoln, Neb.
A Set of Postulates for General Projective Geometry of n Dimensions.

Harold Reynolds Kingston, Assistant Professor of Mathematics, University of Manitoba, Winnipeg, Canada.
Metric Properties of Nets of Plane Curves.

William Vernon Lovitt, Professor of Mathematics, Colorado College, Colorado Springs, Colo.
A Type of Singular Points for a Transformation of Three Variables.

Forbes Bagley Wiley, Professor of Mathematics, Denison University, Granville, Ohio.
Proof of the Finiteness of Modular Covariants of a System of Binary Form of Cogredient Points.

1915 Allen Fuller Carpenter, Associate Professor of Mathematics, University of Washington, Seattle, Wash.
Ruled Surfaces Whose Flecnode Curves Have Plane Branches.

Charles Ross Dines, Federal Reserve Bank, Chicago, Ill.
Functions of Positive Type and Selected Topics in General Analysis.

Jasper Ole Hassler, Assistant Professor of Mathematics, University of Oklahoma, Norman, Okla.
Plane Nets Periodic of Period Three under the Laplace Transformation.

Olive Clio Hazlett, Assistant Professor of Mathematics, Mount Holyoke College, South Hadley, Mass.
On the Classification and Invariantive Characterizations of Nilpotent Algebras.

Archibald Henderson, Professor of Mathematics, University of North Caroline, Chapel Hill, N.C.
The Twenty-seven Lines upon the Cubic Surface.

† Deceased, October 15, 1914.

1915 Alfred Lewis Nelson, Assistant Professor of Mathematics, University of Michigan, Ann Arbor, Mich.
Plane Nets with Equal Laplace-Darboux Invariants.

Vincent Collins Poor, Instructor in Mathematics, University of Michigan, Ann Arbor, Mich.
A Certain Type of Exact Solution of the Equations of Motion of a Viscous Liquid.

Samuel Watson Reaves, Professor of Mathematics, University of Oklahoma, Norman, Okla.
Metric Properties of Flecnodes on Ruled Surfaces.

Mary Evelyn Wells, Assistant Professor of Mathematics, Vassar College, Poughkeepsie, N.Y.
The Determination of All Inequalities of Certain Types in General Linear Integral Equation Theory.

Chester Henry Yeaton, Professor of Mathematics, School of Engineering of Milwaukee, Milwaukee, Wis.
Surfaces Characterized by Certain Properties of Their Directrix Congruences.

1916 Elmer Daniel Grant, Professor of Mathematics, Earlham College, Richmond, Ind.
The Motion of a Flexible Cable in a Vertical Plane.

Arthur McCracken Harding, Professor of Mathematics, University of Arkansas, Fayetteville, Ark.
On Certain Loci Projectively Connected with a Given Plane Curve.

William Leroy Hart, Associate Professor of Mathematics, University of Minnesota, Minneapolis, Minn.
Differential Equations and Implict Functions in Infinitely Many Variables.

Gillie Aldah Larew, Professor of Mathematics, Randolph-Macon Woman's College, Lynchburg, Va.
Necessary Conditions for the Problem of Mayer in the Calculus of Variations.

Arthur Shepard Merril, Assistant Professor of Mathematics, University of Montana, Missoula, Mont.; Ships' Calculator, U.S. Navy Reserve Forces.
An Isoperimetric Problem with Variable End-Points.

Arthur Richard Schweitzer, Chicago, Ill.
Les Idées directrices de la logique génétique des mathématiques.

David Melville Smith, Assistant Professor of Mathematics, Georgia School of Technology, Atlanta, Ga.
Jacobi's Condition for the Problem of Lagrange in the Calculus of Variations.

Pauline Sperry, Instructor in Mathematics, University of California, Berkeley, Cal.
Properties of a Certain Projectively Defined Two Parameter Family of Curves on a General Surface.

1917 Jacob Millison Kinney, Instructor in Mathematics, Hyde Park High School, Chicago, Ill.
The General Theory of Congruences without Any Preliminary Integration.

Kenneth Worcester Lamson, Instructor in Mathematics, Columbia University, New York, N.Y.
A General Implicit Function Theorem, with an Application to Problems of Relative Minimum.

Flora Elizabeth Le Stourgeon, Assistant Professor of Mathematics, University of Kentucky, Lexington, Ky.

1917 †James Elijah McAtee, Late Instructor in Mathematics, University of Illinois.
Modular Invariants of a Quadratic Form for a Prime Power Modulus.

William Pinkerton Ott, Instructor in Mathematics, University of Nashville, Nashville, Tenn.
The General Problem of the Type of the Brachistochrone with Variable End-Points.

Levi Stephen Shively, Professor of Mathematics and Acting President, Mount Morris College, Mount Morris, Ill.
A New Basis for the Metric Theory of Congruences.

Thomas McNider Simpson, Jr., Professor of Mathematics, Randolph-Macon College, Roanoke, Va.
Relation between the Metric and Projective Theories of Space Curves.

1918 Israel Albert Barnett, Assistant Professor of Mathematics, University of Saskatchewan, Saskatoon, Canada.
Differential Equations with a Continuous Infinitude of Variables.

George Hoffman Cresse, Instructor in Mathematics, U.S. Naval Academy, Annapolis, Md.
On the Class Numbers of Binary Quadratic Forms.

Ernest Preston Lane, Assistant Professor of Mathematics, University of Wisconsin, Madison, Wis.
Conjugate Systems with Indeterminate Axis Curves.

Webster Godman Simon, Assistant Professor of Mathematics, Western Reserve University, Cleveland, Ohio.
On the Solution of Certain Types of Linear Differential Equations in Infinitely Many Variables.

1919 Cyril Arthur Nelson, Instructor in Mathematics, Western Reserve University, Cleveland, Ohio.
Conjugate Systems with Conjugate Axis Curves.

1920 Gladys Elizabeth Carson Gibbens, Instructor in Mathematics, University of Minnesota, Minneapolis, Minn.
Comparison of Different Line Geometric Representations for Functions of a Complex Variable.

John Wayne Lasley, Jr., Associate Professor of Mathematics, University of North Carolina, Chapel Hill, N.C.
Some Special Cases of the Flecnode Transformations of Ruled Surfaces.

Irwin Roman, Instructor in Mathematics, Nothwestern University, Evanston, Ill.
The Transformation of Waves through a Symmetrical Optical Instrument.

William Lloyd Garison Williams, Instructor in Mathematics, Cornell University, Ithaca, N.Y.
Fundamental System of Formal Modular Semi-Invariants of the Binary Cubic.

Frank Edwin Wood, Assistant Professor of Mathematics, Michigan Agricultural College, Lansing, Mich.
On Certain Relations between the Projective Theory of Surfaces and the Projective Theory of Congruences.

MATHEMATICAL ASTRONOMY

1900 Forest Ray Moulton, Professor of Astronomy, University of Chicago.
Periodic Oscillating Satellites.

† Deceased.

1903 William Albert Hamilton, Professor of Astronomy, Beloit College, Beloit, Wis.
The True Radii of Convergence for Expansions as Power Series in the Time, in the Case of Parabolic Motion.

1904 Arthur Constant Lunn, Associate Professor of Applied Mathematics, University of Chicago.
The Differential Equations of Dynamics.

1905 Delonzo Tate Wilson, Associate Professor of Mathematics, Case School of Applied Science, Cleveland, Ohio.
Work on Minor Planets.

1906 Frank Loxley Griffin, Professor of Mathematics, Reed College, Portland, Ore.
Certain Periodic Orbits of k Finite Bodies Revolving about a Relatively Large Central Mass.

1908 William Duncan MacMillan, Associate Professor of Astronomy, University of Chicago.
Periodic Orbits about an Oblate Spheroid.

1909 Herbert Earle Buchanan, Professor of Mathematics, Tulane University New Orleans, La.
Periodic Oscillations of Three Finite Masses about the Langrangian Circular Solutions.

1911 Daniel Buchanan, Professor of Mathematics, University of British Columbia, Vancouver, B.C.
A Class of Periodic Solutions of the Problem of Three Bodies, Two of Equal Mass, the Third Moving on a Straight Line.

1913 Lloyd Arthur Heber Warren, Professor of Mathematics, University of Manitoba, Winnipeg, Canada.
A Class of Asymptotic Orbits in the Problem of Three Bodies.

1915 John William Campbell, Assistant Professor of Mathematics, University of Alberta, Edmonton, Alberta.
Periodic Solution of the Problem of Three Bodies in Three Dimensions.

Louis Allen Hopkins, Assistant Professor of Mathematics, University of Michigan, Ann Arbor, Mich.
On the Theory of the Motion of the Small Planets with a Periodic Orbit for the Hilda Type.

PRACTICAL ASTRONOMY AND ASTROPHYSICS

1913 Curvin Henry Gingrich, Assistant Professor of Astronomy, Carleton College, Northfield, Minn.
A Determination of the Photographic Magnitudes of Comparison Stars in Certain Hagen Fields.

Oliver Justin Lee, Instructor in Practical Astronomy, Yerkes Observatory, Williams Bay, Wis.
The Spectroscopic System 9 Camelopardalis.

1914 Frank Craig Jordan, Assistant Professor of Astronomy, University of Pittsburgh, Pittsburgh, Pa.
The Color-Changes of Certain Variable Stars of Short Periods.

1915 Harlan True Stetson, Instructor, Students' Astronomical Laboratory, Harvard University, Cambridge, Mass.
On the Apparatus and on Methods for Thermoelectric Measurements in Photographic Photometry, with Application to the Determination of Magnitude, Spectral Intensities, and the Light Curves of Variable Stars.

1917 Edwin Powell Hubble.
Photographic Investigations of Faint Nebulae, Solar Observatory, Mt. Wilson, Cal.

1919 Hannah Steele Pettit, Chicago, Ill.
The Proper Motions and Parallaxes of 359 Stars in the Cluster h Persei, Derived from Photographs Made with the 40-Inch Refractor of the Yerkes Observatory.

1920 Alice Hall Farnsworth, Instructor, Mount Holyoke College, South Hadley, Mass.
Comparison of the Photometric Fields of the 6-Inch Doublet, 24-Inch Reflector, and 40-Inch Refractor with Some Investigation of the Astrometric Field of the Reflector.

Edison Pettit, Assistant, Mount Wilson Observatory, Pasadena, Cal.
The Forms and Motions of the Solar Prominences.

PHYSICS

1897 Gordon Ferry Hull, Professor of Physics, Dartmouth College; Major in Ordnance, U.S.A.
On the Use of the Interferometer in the Study of Electric Waves.

Isabel Stone, Principal of American School for Girls, Rome, Italy.
On the Electrical Resistance of Thin Films.

1898 Edwin Sheldon Johonnott, Professor of Physics, Rose Polytechnic Institution, Terre Haute, Ind.
Thickness of the Black Spot in Liquid Films.

1899 Henry Gordon Gale, Professor of Physics, University of Chicago.
On the Relation between Density and Index of Refraction of Air.

1900 Robert Francis Earhart, Professor of Physics, Ohio State University.
The Sparkling Potentials between Plates at Small Distances.

1901 Fritz Reichmann, Practical Physicist, Troy, N.Y.
The Capacities of Air Condensers for Very Small Distances between the Plates.

1902 Frank Baldwin Jewett, Vice President and Chief Engineer, Western Electric Co., New York, N.Y.
A New Method of Determining the Vapor-Density of Metallic Vapors.

1904 Thomas Eaton Doubt, Professor of Physics, Armour Institute of Technology, Chicago, Ill.
The Effect of Intensity upon the Velocity of Light.

Fannie Cornelia Frisbee (Mrs. Frank B. Jewett), New York, N.Y.
The Effects of Pressure on Magnetic Induction.

Thomas Carlyle Hebb, Professor of Physics, University of British Columbia, Vancouver, Canada.
The Velocity of Sound.

1905 Frederic Lendhall Bishop, Professor of Physics, University of Pittsburgh, Pittsburgh, Pa.
The Thermal Conductivity of Lead.

Glenn Moody Hobbs, Manager of Testing Laboratory, Sears Roebuck & Co., Chicago, Ill.
The Relation between P.D. and Spark-Length for Small Values of the Latter.

Carleton John Lynde, Professor of Physics, MacDonald College, Quebec, Canada.
The Effect of Pressure on Surface Tension.

1906 William Richard Blair, Major, Signal Corps, U.S. Army, in charge Meteorological Division, Washington, D.C.
The Change of Phase Due to the Passage of Electric Waves through Thin Films.

Lawrence Emery Gurney, Professor of Physics, University of the Philippines, Manila, P.I.
The Viscosity of Water at Low Rate of Shear.

1907 Oliver Charles Clifford, Professor of Electrical Engineering, Armour Institute of Technology, Chicago, Ill.
Susceptibility of Copper and Tin and Their Alloys.

George Winchester, Research Physicist, Standard Oil Co., 26 Broadway, New York City.
Discharge of Electricity from Metals under the Influence of Ultra-Violet Light.

1909 William Ross Ham, Professor of Physics, Pennsylvania State College, State College, Pa.; Captain in Ordnance, U.S.A.
The Polarization of Primary X-Rays.

Charles Albert Proctor, Professor of Physics, Dartmouth College, Hanover, N.H.
The Variation of $\frac{e}{m}$ with Speed in the Case of Cathode Rays.

Newland Farnsworth Smith, Professor of Physics, The Military College of South Carolina, The Citadel, Charleston, S.C.
Effect of Tension on Thermal and Electrical Conductivity.

1910 Louis Begeman, Professor of Physics, Iowa State Teachers College, Cedar Falls, Iowa.
The Determination of "E" by the Cloud Method.

J. Harry Clo, Professor of Physics, University of Pittsburgh, Pittsburgh, Pa.
The Effect of Temperature upon the Ionization of Gas.

Ansel Alphonso Knowlton, Professor of Physics, Reed College, Portland, Ore.
Preparation and Testing of Heusler Alloys.

John Mathias Kuehne, Professor of Physics, University of Texas, Austin, Tex.
The Electrostatic Effect of a Changing Magnetic Field.

James Remus Wright, Research Physicist, Standard Oil Co. of Indiana, Whiting, Ind.
Photo-electric Effects of Aluminum as a Function of the Wave-Length of the Incident Light.

1911 Harold De Forest Arnold, Head of Research Laboratory, Western Electric Co., New York, N.Y.
Limitations Imposed by Slip and Inertia Terms upon Stokes Law for the Motion of Spheres through Liquids.

†Edwin Sherwood Bishop.
A Determination of the Minimum Ionizing Kinetic Energy of an Electron in a Gas.

Harvey Fletcher, Research Laboratory, Western Electric Co., New York, N.Y.
A Verification of the Theory of Brownian Movements and a Direct Determination of the Value of Ne for Gaseous Ionization.

Harvey Brace Lemon, Assistant Professor of Physics, University of Chicago.
The Influence of Temperature upon the Intensities of the Lines of the Hydrogen Spectrum.

† Deceased.

1911 HOWARD WILSON MOODY, Professor of Physics, Mississpppi Agricultural College, Agricultural College, Miss,
A Determination of the Ratio of the Specific Heats and the Specific Heat at Constant Pressure of Air and Carbon Dioxide.

1913 LACHLAN GILCHRIST, Instructor in Physics, University of Toronto; Captain, British Army.
An Absolute Determination of the Viscosity of Air.

EDWARD JAMES MOORE, Professor of Physics, University of Buffalo, Buffalo, N.Y.
Reaction Effects Produced by the Discharge of Electricity from Points in Gases and the Bearing of These Effects on the Theory of the Small Ion.

1914 ALBERT EDWARD HENNINGS, Professor of Physics, University of British Columbia, Vancouver, B.C.
A Study of the Contact Potentials and Photo-electric Properties of Metals *in Vacuo*.

VERNE FRANK SWAIM, Professor of Physics, Bradley Polytechnic Institute, Peoria, Ill.
The Pressure-Shift of Lines in the Spectrum of Zinc.

1915 WILLIAM HENRY KADESCH, Instructor in Physics, U.S. Naval Academy, Annapolis, Md.
The Energy of Photo-Electrons from Sodium and Potassium as a Function of the Frequency of the Incident Light.

JOHN YUI-BONG LEE, 520 Alin Street, Oakland, Cal.
The Determination of "e" by the Millikan Method Using Solid Spheres.

ISAIAH MARCH RAPP, Professor of Physics, University of Montana, Missoula, Mont.
The Flow of Air through Capillary Tubes.

OSCAR WILLIAM SILVEY, Professor of Physics, Texas Agricultural and Mechanical College, College Station, Tex.
A Comparison of the Fall of a Droplet in a Liquid and in a Gas.

1916 ARTHUR JEFFERY DEMPSTER, Assistant Professor of Physics, University of Chicago.
The Properties of Slow Canal Rays.

ERTLE LESLIE HARRINGTON, Professor of Physics, University of Saskatchewan, Saskatoon, Canada.
A Redetermination of the Absolute Value of the Coefficient of Viscosity of Air.

YOSHIO ISHIDA, Physicist, Imperial Institute, Tokyo, Japan.
The Kinetic Theory of Rigid Molecules.

LEONARD B. LOEB, National Research Fellow, Ryerson Laboratory, University of Chicago.
Mobility of Gaseous Ions in High Electric Fields.

CARL DANFORTH MILLER, Associate Professor of Physics, University of Manitoba, Winnipeg, Canada.
Absorption Coefficients of Soft X-Rays.

BENJAMIN ESTILL SHACKELFORD, The Westinghouse Co., New York, N.Y.
Temperature and Blackening Effects in Helical Tungsten Filaments.

WILLIAM HENRY SOUDER, Physicist at Bureau of Standards, Washington, D.C.
The Normal Photo-electric Effect of Lithium, Sodium, and Potassium as a Function of Wave-Lengths and Incidental Energy.

WALTER TICKNOR WHITNEY, Assistant Professor of Physics, California Institute of Technology, Pasadena, Cal.
The Pole Effect in a Calcium Arc.

1917 KARL KELCHNER DARROW, Research Physicist, Western Electric Co., New York, N.Y.
Preliminary Report on a New Method for Determining the Velocity of Sound in Gases.

VICTOR HUGO GOTTSCHALK, Chemist, American Cotton and Oil Co., Chicago, Ill.
The Nature of the Process of Ionization by Alpha Rays.

LEOPOLD JOSEPH LASSALLE, Professor of Mechanical Engineering, University of Louisiana, Baton Rouge, La.
The Law of Fall of a Sphere through Carbon Dioxide and an Exact Determination of the Viscosity of That Gas.

MARGARET CALDERWOOD SHIELDS, Department of Physics, Mount Holyoke College, South Hadley, Mass.
A Determination of the Ratio of the Specific Heats of Hydrogen at 18 Degrees and −190 Degrees.

1919 JOHN BEWLEY DERIEUX, Associate Professor of Physics, North Carolina State College, Raleigh, N.C.
I. The Use of Mercury Droplets in Millikan's Experiment. II. Photo-Electric Effects on Mercury Droplets.

CHARLES FREDERICK HAGENOW, Associate Professor of Physics, Washington University, St. Louis, Mo.
Thermionic and Photoelectric Phenomena at the Lowest Attainable Pressures.

MERVIN JOE KELLEY, Research Physicist, Western Electric Research Laboratory, New York, N.Y.
The Valency of Photo-Electrons and the Photo-electric Properties of Some Insulators.

HAROLD W. NICHOLS, Theoretical Physicist, Western Electric Research Laboratory, New York, N.Y.
Theory of Variable Dynamical-Electrical Systems.

RALPH ALANSON SAWYER, Instructor in Physics, University of Michigan, Ann Arbor, Mich.
Metallic Spark Spectra in the Extreme Ultra-Violet.

LELAND J. STACEY, Telephone Development Engineer, Western Electric Co., New York, N.Y.
A Determination by the Constant-Deflection Method of the Value of the Coefficient of Slip for Rough and for Smooth Surfaces in Air.

1920 IRA GARNETT BARBER, Research Physicist, Linde Air Products Company, Buffalo, New York.
Secondary Electron Emission from Copper Surfaces.

OSWALD BLACKWOOD, Assistant Professor of Physics, University of Pittsburgh, Pittsburgh, Pa.
On the Existence of Homogeneous Groups of Large Ions.

OTTO KOPPIOS, Assistant Professor of Physics, Oberlin College, Oberlin, Ohio.
A Comparison of the Thermionic and Photoelectric Work-Functions in Platinum.

HAROLD HORTON SHELDON, Instructor in Physics, University of Michigan, Ann Arbor, Mich.
Charcoal Activation.

CHEMISTRY

1894 ADOLPH BERNHARD, State Normal School, La Crosse, Wis.
Ueber die Einführung von Acylen in den Benzoylessigaether.

WARREN RUFUS SMITH, Professor and Head of the Department of Chemistry, Lewis Institute, Chicago, Ill.
On the Addition Products of the Aromatic Isocyanides.

1896 Bernard Conrad Hesse, Consulting Chemist, General Chemical Co., New York City.
On Malonic Nitrile and Some of Its Derivatives.

Samuel Ellis Swartz, Professor of Chemistry and Physics, Fairmount College, Wichita, Kan.
The Action of Sodium Ethylate on Amide Bromides.

1897 James Bert Garner, Professor and Head of Department of Chemical Engineering, University of Pittsburgh, and Director of Research, Hope Natural Gas Co., Pittsburgh, Pa.
Condensations with Benzoin by Means of Sodium Ethylate.

Lauder William Jones, Research Professor of Organic Chemistry Princeton University, Princeton, N.J.
On Salts of Nitroparaffine and Acylated Derivatives of Hydroxylamine.

1898 Frank Burnett Dains, Professor of Chemistry, University of Kansas Lawrence, Kan.
On the Isourea Ethers and Other Derivatives of Ureas.

Otto Folin, Hamilton Kuhn Professor of Biological Chemistry, Harvard Medical School, Boston, Mass.
On Urethanes.

Elizabeth Jeffreys, Professor of Chemistry, Pritchett College, Glasgow, Mo.
On Undecylamine and Pentadecylamine and the Preparation of the Higher Amines of the Aliphatic Series.

Herbert Newby McCoy, Vice-President, Linsay Light Co., Chicago, Ill.
On the Hydrochlorides of Carbo-phenylimido Derivatives.

1899 John Charles Hessler, Professor and Head of Department of Chemistry, Knox College, Galesburg, Ill.
On Alkyl Malonic Nitriles and Their Derivatives.

William McPherson, Professor and Head of the Department of Chemistry and Dean of the Graduate School, Ohio State University, Columbus, Ohio.
On the Nature of the Oxyazo Compounds.

James Harvey Ransom, Professor and Head of the Department of Chemistry, James Millikin University, Decatur, Ill.
On the Molecular Rearrangement of o-Aminophenyl Ethyl Carbonate to o-Oxyphenylurethane.

1900 Henry Chalmbers Biddle, Chemist, Berkeley, Cal.
Ueber Derivate des Isuretins, der Formhydroxamsäure und ihre Beziehungen zur Knallsäure.

1901 Ralph Harper McKee, Professor of Chemical Engineering, Columbia University, New York, N.Y., and Director of Research Laboratory, Tennessee Copper Co., Ridgewood, N.J.
On the Oxygen Ethers of the Ureas: Methyl- and Ethylisourea.

1902 Solomon Farley Acree, Research Chemist, National Wood Chemical Association, Syracuse, N.Y.
On Sodium Phenyl and the Action of Sodium on Ketones.

Wallace Appleton Beatty, New York, N.Y.
The Action of Carbon Monoxide on Sodium Alcoholates Alone and in the Presence of Salts of Fatty Acids.

Eugene Paul Schoch, Professor and Chairman of the School of Chemistry and Chairman of the School of Chemical Engineering, University of Texas, Austin, Tex.
The Red and the Yellow Mercuric Oxides and the Mercuric Oxychlorides.

1902 Edwin Emery Slosson, Editor, *Scientific News Service*, Washington, D.C.
On Acylhalogenamine Derivatives and the Beckmann Rearrangement.

1903 Henry Tabor Upson, President and Treasurer, Pease Oil Co., Buffalo, N.Y.
The Molecular Rearrangement of Aminophenylalkyl Carbonates.

1904 Maxwell Adams, Professor of Chemistry, University of Nevada, Reno, Nev.
On Some Hydroxylamine Compounds.

Raymond Foss Bacon, Director of the Mellon Institute of Industrial Research, University of Pittsburgh, Pittsburgh, Pa.
On the Reactions of Sodium Benzhydrol.

William McAfee Bruce, Manager, Eastern Arkansas Demonstration Farm, Blackton, Ark.
On the Oxygen Ethers of Urea.

Nellie Esther Goldthwaite, Associate Professor of Home Economics, Colorado State Agricultural College, Fort Collins, Colo.
On Substituted Benxhydrol Derivatives and Bromcyanacetic Ether.

Oswin W. Wilcox, Chief Chemist and Superintendent, Aetna Explosives Co., Mount Union, Pa.
On the Reactions of Ethyl Chlorsulphonate.

1905 William Lloyd Evans, Professor of Chemistry, Ohio State University, Columbus, Ohio.
On the Behavior of Benzoyl Carbinol toward Alkalies and Oxidizing Agents.

William McCracken, Professor of Natural Sciences, State Normal School, Kalamazoo, Mich.
Studies in Catalysis. V. The Catalysis of Imidoesters.

Herman I. Schlesinger, Associate Professor of Chemistry, University of Chicago, Chicago, Ill.
Studies in Catalysis. VI. The Catalysis of Imidoesters.

1906 Roy Hutchinson Brownlee, Consulting Chemist, Pittsburgh, Pa.
On Precipitated Sulphur.

Charles M. Carson, Professor and Head of the Department of Chemistry, Houghton School of Mines, Houghton, Mich.
On Amorphous Sulphur: Further Study of the Two Forms of Liquid Sulphur as Dynamic Isomers.

Henry Max Goettsch, Assistant Professor of Technical Chemistry, University of Cincinnati, Cincinati, Ohio.
The Absorption Coefficients of Uranium Compounds.

Willis Stose Hilpert, Vice-President, The Miner Laboratories, Chicago, Ill.
Stereoisomeric Chlorimido Acid Esters.

James Wright Lawrie, Research Chemist, E. I. du Pont de Nemours and Co., Wilmington, Del.
The Chemistry of the Acetylidene Compounds.

Andrew Fridley McLeod, Professor of Organic Chemistry, Carleton College, Northfield, Minn.
On Aldol, Pentaerythrose, and the Action of Copper Acetate on the Hexoses.

1907 †Edith Ethel Barnard
The Catalysis of Imidoesters as Affected by the Presence of Non-Electrolytes and Electrolytes.

† Deceased.

1907 KATHERINE BLUNT, Associate Professor of Food Chemistry and Chairman of the Department of Home Economics, University of Chicago, Chicago, Ill.
The Formation of Amidines.

WILLEY DENIS, Assistant Professor of Chemistry, Tulane University, New Orleans, La.
On the Behavior of Various Aldehydes, Ketones, and Alcohols toward Oxidizing Agents.

ROBERT ANDERSON HALL, Research Chemist, Colgate and Co., New York, N.Y.
The Action of Amonia on Isourea Esters.

LOUIS ALLEN HIGLEY, Professor of Chemistry, New Mexico College of Agriculture and Mechanical Arts, State College, N.M.
On the Behavior of Sodium and Sodium Alcoholates toward Various Esters.

WILLIAM HORACE ROSS, Research Chemist, Bureau of Soils, Department of Agriculture, Washington, D.C.
On the Relation between the Radioactivity and the Composition of Thorium and Uranium Minerals.

LOUIS A. TEST, Professor of General Chemistry, Purdue University, Lafayette, Ind.
The Rearrangement of o-Amino-Phenyl Esters.

1908 GEORGE CROMWELL ASHMAN, Professor of Chemistry, Bradley Institute, Peoria, Ill.
Studies in Radioactivity.

1909 EARNEST ANDERSON, Professor of Chemistry, University of Nebraska, Lincoln, Neb.
The Action of Fehling's Solution on *d*-Galactose.

WILLIAM WELDON HICKMAN, Professor of Chemistry, Assuit College, Assuit, Egypt.
The Catalysis of Imidoesters.

WINFORD LEE LEWIS, Professor and Head of the Department of Chemistry, Northwestern University, Evanston, Ill.
On the Action of Fehling's Solution on Malt Sugar.

PETER POWELL PETERSON, Ranch Owner, Idaho Falls, Idaho.
Stereoisomerism of Chlorimido-Ketones.

LEMUEL CHARLES RAIFORD, Professor of Chemistry, University of Iowa, Iowa City, Iowa.
Chlorimido Quinones.

HERMAN AUGUSTUS SPOEHR, Chemical Plant Physiologist, Carnegie Institution, Carmel, Cal.
The Behavior of the Ordinary Hexoses toward Hydrogen Peroxide in the Presence of Alkaline Hydroxides as Well as of Various Iron Salts.

1910 EMMA PERRY CARR, Professor and Head of the Department of Chemistry, Mount Holyoke College, Mount Holyoke, Mass.
The Aliphatic Imidoesters.

ELBERT EDWIN CHANDLER, Professor of Chemistry, Occidental College, Los Angeles, Cal.
Ionization Constants of the Second Hydrogen Ion of Dibasic Acids.

IRA HARRIS DERBY, Consulting Chemist, Republic Creosoting Co., Indianapolis, Ind.
Studies in Catalysis of Imidoesters, IV.

STEWART JOSEPH LLOYD, Professor and Head of the Department of Chemistry and Metallurgy, University of Alabama, University, Ala.
Studies in Radioactivity.

1910 Alan W. C. Menzies, Professor of Chemistry, Princeton University, Princeton, N.J.
Studies in Vapor-Pressure.

John Colin Moore, Instructor in Chemistry, Toledo Heights High School, Chicago, Ill.
The Action of Water on Acyl Isoureas.

William Cabler Moore, Research Chemist, U.S. Industrial Alcohol Co., Baltimore, Md.
Studies in Organic Amalgams.

Fred Wilbert Upson, Professor and Head of the Department of Chemistry, University of Nebraska, Lincoln, Neb.
On the Action of Normal Barium Hydroxide on d. Glucose and d. Galactose.

1911 Thomas Bruce Freas, Associate Professor of Chemistry, Columbia University, New York, N.Y.
A Study of Thermostats.

John Foote Norton, Assistant Professor of Bacteriology, University of Chicago.
Simultaneous Reactions in Amidine Formation.

Harlan Leo Trumbull, Research Chemist, Goodrich Co., Akron, Ohio.
The Molecular Rearrangement of Acid Chloramides and the Ionization of Their Salts.

Leroy Samuel Weatherby, Professor of Chemistry, University of Southern California, Los Angeles, Cal.
The Salt-Effects of the Nitrates and Sulphonates in the Catalysis of Imidoesters.

Franklin Lorinzo West,Director, School of General Science, Professor Physics, Utah Agricultural College, and Physicist, Utah Experiment Station, Logan, Utah.
The Physical and Chemical Properties of Organic Amalgams.

1912 Paul David Potter, Chief Chemist, Sprague, Warner & Co., Chicago, Ill.
The Hydrates of Arsenic Pentoxide.

Charles Herman Viol, Chief Chemist, Standard Chemical Co., Pittsburgh, Pa.
The Chemical Properties and Relative Activities of the Radio-Products of Thorium.

1913 George Oliver Curme, Jr., Assistant Professor of Chemistry, University of Pittsburgh, and Research Chemist, Mellon Institute of Industrial Research, Pittsburgh, Pa.
The Thermal Decomposition of the Symetrical Diaryl-Hydrazines.

John William Edward Glattfeld, Assistant Professor of Chemistry, University of Chicago.
The Oxidation of *d*-Glucose in Alkaline Solution by Air as Well as by Hydrogen Peroxide.

Paul Nicholas Leech, Research Chemist, American Medical Association, Chicago, Ill.
The Molecular Rearrangement of Triaryl Methyl Hydroxylamines; a New Interpretation for the Rearrangement of Ketoximes.

Ethel Mary Terry, Assistant Professor of Chemistry, University of Chicago.
The Velocity Coefficient of Saponification of Ethyl Acetate.

1914 Harold Stanard Adams, Research Chemist, U.S. Rubber Co., Naugatuck, Conn.
Studies in Overvoltage.

1914 Arthur Wesley Martin, Professor of Chemistry and Physics, University of Nanking, Nanking, China.
Studies on Solutions in Anhydrous Formic Acid.

Agnes Fay Morgan, Associate Professor of Household Science, University of California, Berkeley, Cal.
I. Viscosities of Various Methyl and Ethyl Imidobenzoates and of the Sodium Salts of Para and Meta Nitrobenzoyl-chloroamides in Moderately Concentrated Aqueous Solutions. II. The Molecular Rearrangement of Some Triaryl Methylchloroamines.

Harry Morrill Paine, Research Chemist, Atlantic Dyestuffs Co., Boston, Mass.
The Effects of Salts on the Solubility of Other Salts: 1. The Solubility Relations of a Very Soluble Bi-univalent Salt. 2. The Ionization of Bi-bivalent Salts.

Harley Martin Plum, Chemist, Standard Chemical Co., Pittsburgh, Pa.
The Extraction and Separation of the Radioactive Constituents of Carnotite.

Bert Allen Stagner, Research Chemist, San Francisco, Cal.
On the Molecular Rearrangements of Triarylmethyl Hydroxylamines.

Clare Chrisman Todd, Professor of Chemistry, Washington Agricultural College, Pullman, Wash.
The Action of Alkaline Hydrogen Peroxide on d. Galactose.

1915 Clifford Daniel Carpenter, Associate Professor of Chemistry, Columbia University, New York City.
The Addition Compounds of Organic Substances with Sulphuric Acid.

Oscar Fred Hedenburg, Research Chemist, Mellon Institute of Industrial Research, Pittsburgh, Pa.
On the Esters, as well as the Monomolecular β- and γ-Lactones of d-Mannonic and d-Gluconic Acids; On Ortho Bis-d-Galactonic Acid, d-Galactonic γ-Lactone and Its Mono-Hydrate.

Edmund Charles Humphrey, Chemist, E. I. du Pont de Nemours Co., Wilmington, Del.
Surface Tension at the Interface between Two Liquids.

Townes Randolph Leigh, Professor and Head of the Department of Chemistry, University of Florida, Gainesville, Fla.
On Chlorimido Esters and Chlorimido Benzil.

Edwin Daniel Leman, Research Chemist, Radium-Luminous Co., Orange, N.J.
The Relation between the Alpha-Ray Activities and Ranges of Radioactive Substances.

Helen Tredway (Mrs. Evarts A. Graham), c/o Dr. E. A. Graham, Washington University, St. Louis, Mo.
The Thermal Decomposition of Diaryl Hydrazines.

Ernest Dana Wilson, Research Chemist and Superintendent, Graton and Knight Mfg. Co., Worcester, Mass.
The Structure of Complex Atoms.

1916 Groves Howard Cartledge, Associate Professor of Chemistry, Johns Hopkins University, Baltimore, Md.
A Study of the Emanation Method of Determining Thorium.

Clyde Coleman, Research Chemist, Ault & Wiborg Co., Cincinnati, Ohio.
Further Studies on the Behavior of the Alkali Metal Formates in (Anhydrous) Formic Acid.

1916 RALPH EDWIN HALL, Research Chemist, Koppers Co., Mellon Institute of Industrial Research, Pittsburgh, Pa.
The Periodic System and the Properties of the Elements. The Free Energy of Dilution. The Freezing-Point Lowerings of Some Salts of Various Types of Ionization and of Salt Mixtures.

LAWRENCE MELVIN HENDERSON, Assistant Professor of Physical Chemistry, The University of Minnesota, Minneapolis, Minn.
The Ratio of Mesothorium to Thorium in Minerals.

WILLIAM TUDOR PEARCE, Professor of General Chemistry, North Dakota Agricultural College, Agricultural College, N.D.
Ionization and Solubility Relations of Salts of Higher Types, Intermediate Ions in Solutions of Unibivalent Salts and of Lanthanum Iodate, a Triunivalent Salt. II, Solubilities of Very Soluble Higher Type Salts.

WILLARD ALLEN ROBERTS, Research Chemist, General Electric Company, Harrison, N.J.
Studies on the Cobalt-Ammines.

STANLEY DAVIS WILSON, Assistant Professor of Chemistry, Union Medical College, Peking, China.
The Effect of Added Salts upon the Velocity of Saponification of Ethyl Acetate by Sodium Hydroxide.

1917 LESTER ARONBERG, Research Chemist, Diana Chemical Co., Chicago, Ill.
The Spectrum of the Isotopes of the Lead. The Structure of the Bismuth Line $x = 4722$A.

RALPH LYMAN BROWN, Research Chemist, U.S. Bureau of Mines, Pittsburgh, Pa.
The Molecular Rearrangement of Sym. Di-triphenylmethylhydrazine.

SIDNEY MARSH CADWELL, Research Chemist, United States Rubber Co., New York, N.Y.
The Beckmann Rearrangement: Determinations of Minute Quantities of Gold.

EARL CLAUDIUS HAMILTON DAVIES, Associate Professor of Chemistry, University of West Virginia, Morgantown, W. Va.
The Orientation of Molecules in the Surface of Liquids, the Energy Relations at Surfaces, Solubility, Adsorption, Emulsification, Molecular Association, and the Effects of Acids and Bases on Interfacial Tension.

ADELINE MAE DE SALE (Mrs. George K. Link), Assistant Professor of Chemistry, Lawrence College, Appleton, Wis.
The Velocity of Rearrangement of Benzoylazid.

MILTON THEODORE HANKE, Research Instructor, Sprague Memorial Institute, University of Chicago.
The Oxidation of Maltose in Alkaline Solutions by Hydrogen Peroxide and by Air. The Preparation and Study of Maltobionic Acid.

FRANK HYNES REED, Supervisor of Industrial Research, Butterworth Judson Corporation, Newark Transfer, N.J.
Studies in Conductivity. (A) Some Common Errors in the Determination of the Conductivity of Solutions. (B) The Behavior of Mixtures of Two Salts Containing a Common Ion, in Anhydrous Formic Acid Solutions.

JAMES KUHN SENIOR, Research Chemist, Fries and Fries, Cincinnati, Ohio.
Molecular Rearrangements in the Triarylmethylazide and Triarylmethylhydrazine Series.

HERBERT JOHNSON SMITH, Associate Professor of Chemistry, Mississippi Agricultural and Mechanical College, Agricultural College, Miss.
Solubility Products of Carbonates.

1917 Ralph Kempton Strong, Professor of Chemistry, Reed College, Portland, Ore.
Mesothorium-One and Radium; Their Isotopism and Enrichment.

William De Garmo Turner, Professor and Head of the Department of Chemistry, School of Mines, University of Missouri, Rolla, Mo.
The Diffusion of Gases and the Density of Chlorine. A Search for Possible Isotypes of Chlorine.

1918 Denton Jacobs Brown, Assistant Professor of Chemistry, University of Nebraska, Lincoln, Neb.
The Velocity of Decomposition of Benzoyl Peroxide.

Frank Emerson Brown, Assistant Professor of Chemistry, Iowa State College, Ames, Iowa.
1. The Structure of the Surfaces of Liquids and Solubility as Related to the Work Done by the Attraction of Two Liquid Surfaces on Each Other. 2. A Standardization of the Method for the Determination of Surface Tension or Free Surface Energy by the Drop-Weight Method. 3. A Simple Apparatus for the Determination of Surface Tension.

Elmer Newman Bunting, Research Associate in Ceramics, University of Illinois, Champaign, Ill.
Transport Numbers of Potassium, Sodium, and Calcium Formates in Anhydrous Formic Acid.

George Lindenberg Clark, Associate Professor of Physical Chemistry, Vanderbilt University, Nashville, Tenn.
1. The Structure of the Surfaces of Liquids. 2. Secondary Valence and Werner's Coördination Number.

Wilby T. Gooch, Professor of Chemistry, Baylor University, Waco, Tex.
1. Effect of Light on the Velocity of Saponification of Ethyl Acetate. 2. The Velocity Coefficient of the Saponification of Methyl Acetate.

Homer Henry Helmick, Research Chemist, Radium Company of Colorado, Denver, Colo.
A New Method for the Determination of Thorium in Monazite Sand.

Herbert Hiram King, Professor and Head of the Department of Chemistry, Kansas State Agricultural College, Manhattan, Kan.
1. The Structure of Liquids: Adsorption at Liquid—Liquid Interfaces and the Partition of a Solute between Two Liquids. 2. The Structure of Liquids: Adsorption, Solubility and the Double Electric Layer.

Raymond David Mullinix, Professor of Chemistry, Rockford College, Rockford, Ill.
Potassium Permanganate. Studies in Conductivity IV.

Ralph Emory Nelson, Assistant Professor of Chemistry, Purdue University, Lafayette, Ind.
The Coefficient of the Velocity of the Reaction between Sodium Hydroxide and Ethyl Acetate.

Stephen Popoff, Instructor in Chemistry, Iowa State University, Iowa City, Ia.
Studies of Manganates and Permanganates. I. The Course of the Action between Manganese Dioxide, Potassium Hydroxide and Oxygen, and the Manufacture of Potassium Permanganate.

Edward Noel Roberts, Research Chemist, U.S. Industrial Alcohol Co., Curtis Bay, Baltimore, Md.
Velocity of Saponification of Ethyl Formate.

Harry Clyde Trimble, Associate Professor of Chemistry, University of North Dakota, University, N.D.
The Effect of Electric Currents in Attempts to Induce Molecular Rearrangements.

1919 Ray Quincy Brewster, Assistant Professor of Chemistry, University of Kansas, Lawrence, Kan.
I. Symmetrical Tetrapropylethane. II. Reduction of Nitrotriphenylamine.

Elvah Harley Grafton, Research Chemist, Quaker City Rubber Co., Co., Philadelphia, Pa.
The Adsorption of Benzene Derivatives on the Surface of Water. The Work Done by the Attraction between a Mercury Surface and the Surface of an Organic Liquid.

Morris Selig Kharasch, National Research Fellow, National Research Council, University of Chicago, Chicago, Ill.
Colors of the Second Order. Mercuri-Organic Derivatives.

George Elmer Miller, Research Chemist, The Upjohn Co., Kalamazoo, Mich.
Preparation of Pure Cyanogen Chloride; Preparation and Study of of d- and l-Beta-Gamma-Dioxybutyric Acid.

Charles H. Milligan, Research Fellow, John Hopkins University, Baltimore, Md.
The Preparation of dl-P-Methyl-Isopropyl Methyl-Phenyl Hydrazine. The Isolation of Pure d-P-Methyl-Isopropyl Methyl-Phenyl Aniline.

Lathrop Emerson Roberts, Assistant Director of Chemical Research, American Writing Paper Co., Northampton, Mass.
A Study of Phase Boundaries.

Henry John Rossbacher, Chemist, Western Electric Company, Chicago, Ill.
M-Tolyl-Ethyl-Barbituric Acid.

Karl Theodor Steik, Chemical Librarian, Standard Oil Co. of Indiana, Whiting, Ind.
The Effect of Alkali upon Portland Cement.

1920 Steward Basterfield, Assistant Professor of Chemistry, University of Saskatchewan, Saskatoon, Sask., Canada.
Derivatives of Isourea and Their Pharmacological Action.

Ying Chang Cheng, Assistant Professor of Chemistry, University of Pekin, Pekin, China.
Cohesion, Adhesion, Tensile Strength, Tensile Energy, Negative Surface Energy, Interfacial Tension, and Molecular Attraction.

Amando Clemente, University of the Philippines, Manila, P.I.
The Relation between Pore Size and Adsorption in Charcoal.

Frank Louis DeBeukelaer, Research Chemist, Swift and Co., Chicago, Ill.
Derivatives of Phenylethylacetic Acid and of Phenyldiethylacetic Acid.

Dwight Tarbell Ewing, Professor of Chemistry, Michigan State Agricultural College, East Lansing, Mich.
I. The Densities and Adsorption and Desorption Properties of Gas Mask Charcoals. II. The Effects of Acids and Bases on the Surface Energy of β-β-Dichlorethyl Sulphide ("Mustard Gas").

Warren Walter Ewing, Assistant Professor of Physical Chemistry, Lehigh University, Bethlehm, Pa.
The Attraction of Mercury for Other Liquids.

Louis Melvin Larsen, Research Chemist, Ault and Wiborg Co., Cincinnati, Ohio.
I. Nitrotriphenylamines. II. The Oxidation of Diaminophenolos.

MARY MEDA RISING, Instructor in Chemistry, University of Chicago, Chicago, Ill.

I. The Preparation of Phenylethylbarbituric Acid. II. The Preparation of Para-Ureido-Phenylacetylurea, and Related Compounds. III. An Attempt to Filter the Enzymes of Milk.

JOHN EDWARD SCHOTT, Assistant Professor of Chemistry, Pennsylvania State College, State College, Pa.

I. Oxidation of Benzamide. II. Derivatives of Phenylethylbarbituric Acid.

HERMAN VANCE TARTAR, Assistant Professor of Chemistry, University of Washington, Seattle, Wash.

The Constitution of Murexide and the Theory of Dyes.

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1922–23

THE UNIVERSITY OF CHICAGO PRESS
CHICAGO, ILLINOIS

CALENDAR FOR THE YEAR 1922–23

1922

June 10	Saturday	Alumni Day
June 11	Sunday	Convocation Sunday
June 12	Monday	College Day
June 13	Tuesday	Summer Convocation
June 14	Wednesday	Examinations for the Spring Quarter
June 15	Thursday	
June 16	Friday	
June 16	Friday	Spring Quarter ends
June 17	Saturday	Registration for the Summer Quarter
June 19	*Monday*	*Summer Quarter begins*
June 19–24		Examinations of the College Entrance Examination Board
July 4	Tuesday	Independence Day: a holiday
July 15	Saturday	Special Examinations for removal of deficiencies (work reported conditioned or incomplete) incurred during the last quarter of residence
July 25	Tuesday	Examinations for the First Term of the Summer Quarter
July 26	Wednesday	
July 26	Wednesday	First Term of the Summer Quarter ends
July 27	Thursday	Second Term of the Summer Quarter begins
Aug. 27	Sunday	Convocation Sunday
Aug. 31	Thursday	Examinations for the Second Term of the Summer Quarter
Sept. 1	Friday	
Sept. 1	Friday	Autumn Convocation Summer Quarter ends
Sept. 11–15		Examinations for Admission
Sept. 28–30		Registration for the Autumn Quarter
Sept. 30	Saturday	Special Examinations for all students returning for the Autumn Quarter who incurred deficiencies (work reported conditioned or incomplete) in the last quarter of residence
Oct. 2	*Monday*	*Autumn Quarter begins*
Nov. 30	Thursday	Thanksgiving Day: a holiday
Dec. 17	Sunday	Convocation Sunday
Dec. 19	Tuesday	Winter Convocation
Dec. 20	Wednesday	Examinations for the Autumn Quarter
Dec. 21	Thursday	
Dec. 22	Friday	
Dec. 22	Friday	Autumn Quarter ends

1923

Jan. 2	*Tuesday*	*Winter Quarter begins*
Jan. 27	Saturday	Special Examinations for removal of deficiencies (work reported conditioned or incomplete) incurred during the last quarter of residence
Feb. 12	Monday	Lincoln's Birthday: a holiday
Feb. 22	Thursday	Washington's Birthday: a holiday
Mar. 18	Sunday	Convocation Sunday
Mar. 20	Tuesday	Spring Convocation
Mar. 21	Wednesday	Examinations for the Winter Quarter
Mar. 22	Thursday	
Mar. 23	Friday	
Mar. 23	Friday	Winter Quarter ends
Mar. 24—April 1		Quarterly Recess
April 2	*Monday*	*Spring Quarter begins*
April 28	Saturday	Special Examinations for removal of deficiencies (work reported conditioned or incomplete) incurred during the last quarter of residence
May 10	Thursday	Annual Conference with Co-operating Schools
May 11	Friday	
May 30	Wednesday	Memorial Day: a holiday
June 9	Saturday	Alumni Day
June 10	Sunday	Convocation Sunday
June 11	Monday	College Day
June 12	Tuesday	Summer Convocation
June 13	Wednesday	Examinations for the Spring Quarter
June 14	Thursday	
June 15	Friday	
June 15	Friday	Spring Quarter ends

OFFICERS OF ADMINISTRATION

HARRY PRATT JUDSON, President of the University, Harper Memorial Library, Room W11.

ERNEST DEWITT BURTON, Director of the University Libraries, Harper Memorial Library, Room M27.

NATHANIEL BUTLER, Director of Co-operation with Secondary Schools, Cobb Lecture Hall, Room 11A.

EDGAR JOHNSON GOODSPEED, Secretary to the President, Harper Memorial Library, Room W11.

WALTER A. PAYNE, University Recorder and Examiner, Cobb Lecture Hall, Room 5A.

MARION TALBOT, Dean of Women, Cobb Lecture Hall, Room 9A.

SOPHONISBA PRESTON BRECKINRIDGE, Assistant Dean of Women, Cobb Lecture Hall, Room 9A.

ROLLIN D. SALISBURY, Dean of the Ogden Graduate School of Science, Cobb Lecture Hall, Room 10½A.

DAVID ALLAN ROBERTSON, Dean of the Colleges of Arts, Literature, and Science, Cobb Lecture Hall, Room 14A.

HENRY GORDON GALE, WELLINGTON DOWNING JONES, Cobb Lecture Hall, Room 10A; BASIL COLEMAN HYATT HARVEY, Ellis Hall, Room 24: Deans in the College of Science.

NATHANIEL BUTLER, Dean of University College, Cobb Lecture Hall, Room 11A.

DAVID HARRISON STEVENS, Assistant to the Dean of the Colleges of Arts, Literature, and Science, Cobb Lecture Hall, Room 14A.

GENERAL INFORMATION

The University includes: (1) The Graduate and Professional Schools, viz., the Graduate School of Arts and Literature, the Ogden Graduate School of Science, the Divinity School, the Law School, the School of Education, the School of Commerce and Administration, the Graduate School of Social Service Administration; (2) the Colleges of Arts, Literature, and Science; (3) the Libraries, Laboratories, and Museums; (4) the University Press.

Faculty and equipment —The faculty (exclusive of assistants) numbers three hundred and fifty-five; the libraries contain over 700,000 bound volumes and 200,000 pamphlets (estimated). The University owns nearly one hundred acres of land in Chicago and has forty buildings.

Location of the University.—The University grounds lie on both sides of the Midway Plaisance between Washington and Jackson parks, six miles south of the center of Chicago. Electric cars, elevated trains, and the Illinois Central suburban service reach all railway stations. Mail and baggage service is provided at the Information Office of the University.

The Yerkes Astronomical Observatory is at Williams Bay, Wisconsin, with 170 acres of land on the shore of Lake Geneva.

The University year is divided into quarters: the Autumn (October, November, December); the Winter (January, February, March); the Spring (April, May, to the middle of June); the Summer (from the middle of June, July, August). For the year 1922–23 the exact dates for the opening of the four quarters are: Summer Quarter, June 19, 1922; Autumn Quarter, October 2, 1922; Winter Quarter, January 2, 1923; Spring Quarter, April 2, 1923. Students are admitted at the opening of each quarter; graduation exercises are held at the close of each quarter.

The unit of work and of credit is a *major*, i.e., a course of instruction involving four or five recitations or lecture hours per week for a full quarter, or double that number of hours for a term of six weeks. A *minor* is one-half a major. Normal work is three majors per quarter, or nine per year of three quarters.

Degrees.—The University confers in the Graduate Schools of Arts, Literature, and Science the degrees of Doctor of Philosophy and of Master of Arts and of Science; in the Colleges of Arts, Literature, and Science, the degrees of Bachelor of Arts, of Science, and of Philosophy; in the Divinity School, the degree of Bachelor of Divinity; in the Law School, the degrees of Doctor of Law and of Bachelor of Laws; in the School of Education, the degrees of Bachelor of Arts, of Philosophy, and of Science in Education; in the School of Commerce and Administration, the degree of Bachelor of Philosophy; in the Graduate School of Social Service Administration, the degree of Master of Arts in Social Service Administration.

Fellowships, scholarships, student service, etc.—By virtue of endowments and special appropriations, fellowships and scholarships and service afford stipends or tuition to a number of able and deserving students. The University also maintains a bureau for securing outside employment.

DOCTORS OF PHILOSOPHY AS GUESTS OF THE UNIVERSITY

The President of the University, on recommendation of a Head of a Department, will welcome Doctors of Philosophy of the University of Chicago as well as of other universities as guests of the University, with the privilege of attending seminars and of carrying on research in the laboratories and libraries. There will be no charge except for laboratory supplies and a nominal laboratory fee for laboratory work. Arrangements should be made in advance with the President.

FEES FOR MATRICULATION, TUITION, ETC.

A. *Matriculation fee.*—The matriculation fee is $10.00 and is required of every student on entrance into the University.

B. *Tuition fee.*—

1. The tuition fee in the **Graduate Schools of Arts, Literature, and Science,** and the **Graduate School of Social Service Administration,** is $50.00 a quarter.

2. The tuition fee for students in the **Colleges of Arts, Literature, and Science** and the **College of Education,** and unclassified students, is $60.00 a quarter for regular work (three majors for a quarter); for a fourth major, in addition, $20.00 a quarter.

3. The tuition fee for students in the **School of Commerce and Administration,** including materials fees in that school, is $70.00 a quarter; for students in the **Law School,** $70.00 a quarter; for students in the **Medical Courses,** including laboratory fees, $75.00 a quarter; and for students in the **Divinity School,** $50.00 a quarter.

4. *All tuition and laboratory fees are due on or before the first day of each quarter, and are payable without extra fee up to* 3:00 P.M. *of the fifth day of the quarter at the Office of the Cashier,* Press Building, Room 1.

C. *Fines, etc.*—For failure to pay tuition fees within the first five days of the quarter a fee of $5.00 is added to the bill.

D. *Laboratory fee.*—Students in most laboratory courses pay a laboratory fee of $6.00 a major (M. or DMj. courses will be charged in proportion). In the Departments of Home Economics, Modeling and Ceramics, and Industrial Education, laboratory fees varying from $2.00 to $6.00 are charged for certain courses, depending on the nature of the courses. Twelve dollars ($12.00) is the maximum charge for laboratory work in any one department. In addition to the regular laboratory fee, students in laboratory courses are required to purchase at the office of the Cashier adequate breakage and supply coupon tickets to be deposited as follows: for courses in Chemistry, with the Curator of Kent Chemical Laboratory; for courses in Physiology, with the instructor in charge; for courses in Physiological Chemistry, with the instructor in charge; and for courses in Zoölogy, Anatomy, Botany, Pathology, and Hygiene and Bacteriology, at the laboratory supply store, Room 10, Botany Building. New tickets must be purchased at the opening of each quarter, and a refund of the unused balance on the old tickets can be obtained at that time. In courses requiring the use of a microscope a rental fee, varying with the type of the instrument, is charged.

E. *A small materials fee* is charged in certain courses in Political Economy and Sociology.

F. *Gymnasium locker fee.*—For the use of a locker in the dressing-room of the gymnasium a fee of $1.00 per quarter in the men's gymnasium and $1.50

in the women's gymnasium is charged. A small fee is also charged for the use of the tennis courts.

G. *Graduation fee.*—The general graduation fee, including diploma, is $10.00. The graduation fee for Doctors of Philosophy, including diploma and hood, is $15.00.

ROOMS, BOARD, AND GENERAL EXPENSES

The University has thirteen residence halls for students, eight for women and five for men. Rooms in these halls rent for from $30 to $75 a quarter. The rental covers charges for heat, light, and care, except that in Drexel House the rooms are cared for by the students themselves. Rooms are for the most part single, but a few in each Hall may be occupied by two students. Application for rooms should be made to the University Cashier, who will, on request, send a diagram of the Halls showing prices of rooms. Each room is furnished with study-table, chairs, bookcase, bureau, mirror, chamber-ware, rug, bedstead, mattress, and bedding, with the exception that in Hitchcock Hall rugs are furnished by the students and in Drexel House bedding is furnished by the students. Towels must be furnished by the students. Rooms may not be subrented, nor can exchange or transfer of rooms be made except by permission of the Cashier.

A University House is organized in each Hall; each House has a Head, appointed by the President of the University, and a House Committee, elected by the members; also a House Counselor, selected from the Faculties of the University by the members of the House. The membership of the House is determined by election, and each House is self-governing under the general control of the University.

Six of the halls for women (Beecher, Kelly, Foster, Green, Greenwood, and Kenwood) have separate dining-rooms and parlors. The cost of board in these halls is $7.00 per week and board for the entire quarter is payable in advance on the opening day. All students living in these halls are required to take their meals there.

The table below furnishes an estimate of the annual expenses, exclusive of tuition and laboratory fees, for thirty-six weeks, of a student in the University residing within the quadrangles.

	Lowest	Average	Liberal
Rent and care of room	$ 90.00	$144.00	$288.00
Board	231.00	270.00	330.00
Laundry	45.00	60.00	75.00
Textbooks and stationery	30.00	51.00	72.00
Incidentals	45.00	75.00	120.00
Total	$441.00	$600.00	$885.00

An opportunity to share in co-operative housekeeping and thereby to reduce living expenses somewhat is offered at Drexel House, which accommodates sixteen women students who share in the preparation of meals and the care of the House. Room rent for each student is $36.00 a quarter, and the co-operative plan makes the cost of table board considerably less than is possible under other circumstances. Some experience in housekeeping and adaptability to group life

are necessary. Correspondence with reference to rooms in Drexel House should be addressed to the Director of the Housing Bureau.

The University of Chicago maintains its Housing Bureau in order to assist students in finding the best accommodations obtainable in the University neighborhood. All rooms listed have been inspected and certain standards are maintained. Rooms on small inclosed courts are not listed, and all householders registered must rent exclusively to men, or exclusively to women. The use of a reception room at least two evenings a week must be provided for women students. Students are asked to co-operate by insisting on these requirements even if they do not engage their rooms through the Housing Bureau.

Upon arrival at the University, students should apply at once to the Housing Bureau for a list of rooms. Incoming students are especially cautioned against strangers who approach them at the station or on the streets and offer their services in securing rooms. Because of a general scarcity of housing facilities in Chicago at the present time, it is now more difficult to find satisfactory accommodations than was the case in past years.

Students may secure furnished rooms in the neighborhood of the University at prices ranging from $60.00 to $150.00 a quarter, and take their meals at the University or at nearby restaurants. Men occasionally find small rooms or dark rooms for less than $50.00 a quarter, but women usually have to pay $60.00 or more. Not less than $7.00 a week should be allowed for table board, and one can seldom find a room with outside light, drop light, study table, ample closet space, and a comfortable bed for less than $72.00 a quarter.

Desirable furnished rooms for light housekeeping are difficult to find. They range in price from $30.00 to $75.00 a month. The so-called kitchenettes in buildings in the vicinity of the University are small, usually dark, rooms with a kitchen table and gas plate, but never with running water. Rooms with kitchen privileges may be secured at the regular room rates with an additional charge of about $12.00 per quarter.

Furnished houses or apartments of from four to ten rooms vary in price from $60.00 to $150.00 per month. In the University neighborhood there are very few two- or three-room apartments and their rental, unfurnished, is $50.00 a month or more. The Housing Bureau lists only furnished houses and apartments.

Lists of rooms may be obtained at the office, Room 1, Press Building, about one week before the opening of each quarter. Lists should be obtained in person at this office. Renting by mail is not satisfactory and students are advised against it.

Board at the University may be obtained at Hutchinson Commons, the Ida Noyes refectory, and the Emmons Blaine lunch-room. Cafeteria service is provided, the cost of meals averaging about $7.00 per week.

FELLOWSHIPS AND SCHOLARSHIPS

The University appropriates annually from its general funds the amount of twenty-one thousand one hundred dollars ($21,100) for Fellowships in the Graduate Schools of Arts, Literature, and Science. These Fellowships range in value from $150, the tuition fees of a graduate student for three quarters, to $520, that is, $370 in addition to the tuition fees for three quarters. A limited

number of Scholarships, covering a part or all of the tuition fees for three quarters, are also awarded annually.

Candidates for these Fellowships and Scholarships should send to the Deans of the Graduate Schools of Arts, Literature, and Science a record of their previous work and distinctions, degrees, and past courses of study, with copies of their written or printed work in the field of the department in which application is made. Application must be received at the Deans' offices *not later than March 1 of each year*, in order to be considered for the following year. Appointments are made April 1.

Fellows may be called upon for assistance in teaching in the University, or for kindred work; but in no case will they be expected or permitted to devote so much time to this work as to prevent the successful prosecution of their own work as students. Fellows will not engage in outside work for compensation, unless by permission of the President. Except in rare cases, students will not be appointed to Fellowships until they have done at least one year of graduate work.

In addition to the Scholarships mentioned above, a number of graduate Scholarships, each yielding a sum sufficient to pay the annual tuition fees, are awarded annually to students graduated from the University of Chicago during the preceding year, who are recommended to the Committee on Scholarships on the basis of excellence of record in their respective departments of specialization.

Full particulars concerning higher degrees, Fellowships, Scholarships, and other matters of interest to graduate students will be found in the *Handbook of the Graduate Schools of Arts, Literature, and Science*, which will be sent upon application.

AID TO STUDENTS

Besides Fellowships and Scholarships various kinds of assistance are offered to those who need help, under the following heads: Prizes, University Service, Loans by the Students' Fund Society, and Outside Employment. The position of the University in a large city brings the decided advantage of providing many opportunities for employment. Through the University Employment Bureau many students are able to secure all of the outside employment for which they have time. For further details applicants should send for the circular entitled *Awards and Aids*.

DEGREES

Graduate study may lead to a Master's or to a Doctor's degree under the conditions specified below:

I. THE MASTER'S DEGREE

Two degrees are conferred, viz., *Master of Arts* and *Master of Science*.

1. *Candidacy.*—Any member of the Graduate Schools who has been in attendance one quarter or more, and whose undergraduate course is equivalent to that required for a corresponding Bachelor's degree in the University of Chicago,[1] and whose thesis subject has been accepted by the department con-

[1] Attention is particularly called to the fact that the term "equivalent" in this connection refers to quantity only. It does not affect the question of the specific Master's degree (Arts or Science) to which a given student's work would lead. In case the candidate did not obtain his Bachelor's degree at the University of Chicago, he will present to the Examiner on blanks furnished for the purpose a detailed statement of his undergraduate work. The Examiner cannot always report upon these statements during the opening week of the quarter.

cerned, may, on recommendation by the department or departments in which he is working, be enrolled, by vote of the Faculties of the Graduate Schools, as a candidate for a Master's degree. Application for admission to candidacy must be made on the blank provided for the purpose. This blank must be obtained by the applicant at the Dean's office, and the application must be on file in that office at least two months before the degree is conferred.

2. *Requirements.*—Students thus accepted as candidates will be given a Master's degree on fulfillment of the following requirements:

a) At least three quarters' residence at the University.

b) At least 8 majors of graduate work at the University of Chicago. These 8 majors need not be all in one department, but must be selected according to some rational plan approved by the Deans of the Graduate Schools at least six months before the degree is conferred. The individual courses must receive the approval of the heads of the department concerned.

c) A satisfactory dissertation on a subject approved by one of the departments in which the work is done.[1] The subject of the dissertation must be approved by the Head of the Department at least three months before graduation, and the dissertation in complete form must be submitted to the Department at least four weeks before the degree is conferred. This period may be lengthened to six weeks at the option of any department.

d) The delivery of three printed or typewritten copies of the dissertation to the University Library at least ten days before the Convocation at which the degree is to be conferred. Two of the copies must be bound.

e) A satisfactory examination on the work taken for the degree.

f) No course completed with a grade below C will count toward the Master's degree.

II. THE DEGREE OF DOCTOR OF PHILOSOPHY

The degree of *Doctor of Philosophy* is given, not on the basis of the completion of a certain amount of time spent upon a specified program, but as the recognition and mark of high attainments and ability in the candidate's chosen province, shown, first, by the production of a dissertation evincing the power of independent investigation and forming an actual contribution to existing knowledge; and, secondly, by the passing of examinations covering the general field of the candidate's subjects, with more detail in the case of the principal subject, with less detail in the case of the secondary subject or subjects.

1. *Candidacy.*—Any member of the Graduate Schools who has been in attendance one quarter or more, whose undergraduate course is equivalent to that required for a Bachelor's degree in the University of Chicago,[2] whose thesis subject has been accepted by the principal department, and who has a reading knowledge of two modern languages other than English, may, on recommendation by the principal department in which he wishes to take his degree, be enrolled, by vote of the Faculties of the Graduate Schools, as a candidate for the Doctor's degree. The languages other than English must be languages which contain

[1] In exceptional cases the Deans, upon the recommendation of the departments concerned, may accept an additional major in lieu of the dissertation.

[2] In case the candidate did not obtain his Bachelor's degree at the University of Chicago, he will present to the Examiner on blanks furnished for the purpose a detailed statement of his undergraduate work. The Examiner cannot always report upon these statements during the opening week of the quarter.

important critical literature of the subject in which the candidate's principal work is done. They must be selected with the approval of the department of principal work and of the Dean, and a reading knowledge of the languages must be certified by the appropriate departments not less than one academic year (9 months) before the final examination for the degree. Application for admission to candidacy must be made on the blank provided for the purpose. This blank must be obtained by the applicant at the Dean's office, and the application must be on file in that office before the close of the quarter preceding that in which the degree is conferred.

2. *Requirements.*—Students accepted as candidates will be given the Doctor's degree on the fulfillment of the following requirements:

a) At least three years of resident work in pursuance of an accepted course of study. The student may follow one of two plans. Plan I: The work offered in fulfillment of the requirements for the Ph.D. degree in any department is outlined by the Department and approved by the Dean, for each candidate, not later than the first quarter of his last year of residence work. The work required will include such courses in departments allied to that of principal work as may be deemed necessary by the principal department to obviate narrow specialization. The work is selected with regard to the needs of the individual student, with the double purpose (1) of giving him a knowledge of the relations of his principal subject to cognate branches of learning, and (2) of preparing him for productive scholarship. All courses offered in fulfillment of the requirement for the degree must be advanced courses, and a list of courses shall be submitted to the Faculties when the applicant is admitted to candidacy. Plan II: Under this plan the work offered must include one principal and either one or two secondary subjects. The amount of work required in the secondary subject or subjects is normally 9 majors. Candidates for the degree of Doctor of Philosophy may not, under this plan, take more than two-thirds of their work in one department, and may not take work which is to count toward the degree in more than three departments.

b) A satisfactory final examination upon the work done in preparation for the degree.

c) The presentation of a satisfactory dissertation upon a subject which has been approved by the Head of the Department in which the principal part of the candidate's work has been done.

d) A good command of literary expression and such knowledge of subjects considered fundamental as may be prescribed by the several departments.

3. *Dissertation.*—Each student is required to prepare a dissertation upon some topic connected with his principal subject. The dissertation must constitute an actual contribution to knowledge. Its subject must be submitted for approval to the Head of the Department at least twelve months before the date of the final examination. The dissertation itself must be submitted to the Head of the Department at least one month before the date of the final examination. This period may be lengthened to six weeks at the option of any department.

Ten days before the Convocation at which the degree is conferred, a typewritten copy of the dissertation, together w th a certificate signed by the Head or acting Head of the Department that the copy, as submitted, is accepted for

publication as the candidate's dissertation for the Doctor's degree, shall be filed in the office of the Deans of the Graduate Schools. Said copy may not be withdrawn from the office of the Deans of the Graduate Schools until the required one hundred copies are deposited in the Library.

The candidate shall deposit in the office of the Deans of the Graduate Schools a contract in legal form to the effect that he will furnish the General Library with one hundred copies (including two bound in half-roan) which shall fulfill in format, cover, title-page, and stock all the University requirements. (See special circular entitled *Handbook of the Graduate Schools of Arts, Literature, and Science.*)

Any one of the following three methods may be followed:

a) A signed statement may be filed in the Graduate Office from a publishing agency approved as to its technical efficiency by the University of Chicago Press, and also as to its professional responsibility by the department concerned, that the dissertation has been received and accepted for publication.

The one hundred copies furnished to the General Library must be separate prints. They must contain no other material and must be put in covers (ninety-eight in paper covers and two in half-roan).

b) The candidate may deposit with the Business Office a legal financial guaranty sufficient to enable the University of Chicago Press to print the required one hundred copies, including the binding of two copies in half-roan. This guaranty shall mature at the expiration of two years from the date of the conferring of the degree.

c) The candidate may at his own cost secure publication of the dissertation in the form prescribed by the University, in which case the degree will be conferred only after the delivery of the required one hundred copies to the General Library.

Additional dissertation regulations:

d) Upon recommendation of a department and approval of the Dean of the Faculty immediately concerned, a form of the Doctor's dissertation briefer than that received in satisfaction of requirements for the degree may be accepted for publication. For instance, the alternative form of publication may be an account of the method pursued in the investigation, together with an abstract of the evidence used and a complete summary of the conclusions reached; or it may be a single chapter, provided the same represents a distinct unit of investigation.

e) In case the briefer form of the Doctor's dissertation is accepted for publication, two typewritten copies of the *complete* dissertation are required for deposit in the library in addition to the printed copies of the briefer form, before the degree is conferred.

f) In case the course provided for in *d*) is adopted, arrangements for the same are made in the Dean's office before the expiration of the term fixed for publication.

g) Clauses *d*)–*f*) are held to modify other rules governing publication of dissertation in the one detail of providing for acceptance of a printed abbreviation in the place of the complete dissertation.

4. *Final examination.*—Plan I (see 2, *a*), p. 10): After admission to candidacy the student may present himself for examination as soon as he has fulfilled (*a*) the requirements of the department, (*b*) the modern language requirement,

and (*c*) the dissertation requirements (see 3, p. 10). The examination will be conducted by a committee consisting of members of the department in which the degree is to be taken, and a representative of some other department, appointed by the Deans of the Graduate Schools. The candidate is required to prepare a typewritten or printed brief of his work, including an analysis of the dissertation, and to file six copies of the same with his Dean for distribution to the committee one week before the time set for the examination. In case of the examination in the secondary department, the statement should include the work in this department, and the statement for the final examination should include the work of both departments.

Plan II (see 2, *a*), p. 10): After admission to candidacy the student may present himself for examination in his secondary subject or subjects as soon as he has fulfilled the requirements of the department or departments concerned. He may present himself for the examination in his principal subject, or in both principal and secondary subjects if the examination in the latter has not been taken in advance (1) as soon as he has fulfilled the requirements of the department or departments concerned, and (2) after he has made satisfactory arrangements as regards his dissertation. The examination will be conducted by a committee consisting of the members of the principal department concerned, an appointed representative of the secondary department, or a representative of each of them if there are two, of any other members of the secondary department who may choose to attend, and a member of some other department appointed by the Deans of the Graduate Schools. If the examination in the secondary subject or subjects is separated from the examination in the principal subject, the two may not be held in the same quarter, nor within two months of each other.

5. *Non-resident work.*—After being admitted, the student may be allowed to substitute non-resident work for resident work to a limited extent, under conditions to be arranged in consultation with the Dean and the heads of the departments concerned.

6. *Work done in other universities.*—Graduate work done in another university will be accepted as equivalent to resident work in the University of Chicago, provided the institution in which the work was done is of high standing, and adequate evidence is furnished that the work done there was satisfactorily performed. Graduate work done in other institutions cannot reduce the residence requirement at the University of Chicago to a period less than one year.[1]

[1] In order to avoid misunderstandings, candidates for higher degrees should consult their Deans concerning all technical requirements for such degrees before application is made for admission to candidacy. In all cases candidates should consult early with the heads of the departments of their major and minor subjects.

THE DEPARTMENT OF MATHEMATICS

OFFICERS OF INSTRUCTION

Eliakim Hastings Moore, Ph.D., LL.D., Sc.D., Math.D., Professor and Head of the Department of Mathematics.

Herbert Ellsworth Slaught, Ph.D., Sc.D., Professor of Mathematics.

George William Myers, Ph.D., Professor of the Teaching of Mathematics and Astronomy, the School of Education.

Leonard Eugene Dickson, Ph.D., Professor of Mathematics.

Gilbert Ames Bliss, Ph.D., Professor of Mathematics.

Ernest Julius Wilczynski, Ph.D., Professor of Mathematics.

Jacob William Albert Young, Ph.D., Associate Professor of the Pedagogy of Mathematics.

Arthur Constant Lunn, Ph.D., Associate Professor of Applied Mathematics.

Mayme Irwin Logsdon, Ph.D., Instructor in Mathematics.

Robert Lee Moore, Ph.D., Associate Professor of Mathematics, University of Texas (Summer, 1922).

Harry Shultz Vandiver, Instructor in Mathematics, Cornell University (Summer 1922).

FELLOWS, 1921–22

Harry Scheidy Everett, S.M. Matthew Moses Feldstein, S.B.
Edgar D. Meacham, A.B.

GENERAL AIMS

The courses in Mathematics are intended for those studying mathematics as a part of a liberal education, for those expecting to apply mathematics in other sciences or in technology, for prospective teachers of mathematics or other sciences in secondary schools, colleges, and universities, and for workers and investigators in the most advanced fields of mathematics.

ARRANGEMENT OF WORK

The student will be aided in planning his work in Mathematics by the classification of courses (in the list given later) as primarily of the Junior College, the Senior College, or the Graduate School, and by the specific prerequisites named for each course. But the proper arrangement of work in mathematics is of such extreme importance that students are urged to consult instructors of the Department in planning their work. For graduate students a formal system of registration is in use which requires personal conference with the instructor of each course to be taken, and quarterly consultation with the departmental adviser selected by the student.

MATHEMATICAL SEQUENCES FOR UNDERGRADUATES

All courses offered by the Department of Mathematics or given numbers in its printed Announcements (called "mathematical majors" in what follows) may be used in mathematical sequences, except as noted in the following paragraph. Courses admissible for sequences in the Departments of Physics and Astronomy

may also be used in mathematical sequences to an amount not greater than one-third of the total number of majors, provided that the most elementary courses from two or more related departments may not be combined in a sequence.

Principal sequences.—A principal sequence may consist of any nine admissible majors provided at least three mathematical majors are included whose numbers are higher than 17.

Secondary sequences.—A secondary sequence may consist of any six admissible majors provided at least one mathematical major is included whose number is higher than 14.

The following are given as illustrations of typical sequences:

MATHEMATICS

Principal Sequences

a) Courses 1, 2, 3, 18, 19, 20, 47, 48, 49.

b) Courses 1, 2, 3, 18, 19, 22, 31, 34, 38 or 40.

Secondary Sequences

a) Courses 1, 2, 3, 18, 19, 20.

b) Courses 1, 2, 3, 15, 22 or 28, 31 or 34.

SEQUENCES FOR PROSPECTIVE TEACHERS

Principal Sequences

a) Courses 1, 2, 3, 18, 19, 22, 31, Ed. Math. 2, 5.

b) Courses 1, 2, 15, 22, and any five of: 28, 31, 34, 37, 38, 40, Ed. Math. 2, 5.

Secondary Sequences

Courses 1, 2, 3, 15, 22 or 31, Ed. Math. 2, 5.

MATHEMATICS AND ASTRONOMY

Principal Sequences

a) Courses 1, 2, 3, 18, 19, 20, Astronomy and Astrophysics 5, 6, 7.

b) Courses 1, 2, 3, 18, 19, 22, Astronomy and Astrophysics 3A, 3B, 4.

Secondary Sequences

a) Courses 1, 2, 3, 15, Astronomy and Astrophysics 1, 7.

b) Courses 1, 2, 3, 15, Astronomy and Astrophysics 3A, 3B.

MATHEMATICS AND PHYSICS

Principal Sequences

a) Courses 1, 2, 3, 18, 19, 47, Physics 3, 4, 5, or 3S, 4S, 7.

b) Courses 1, 2, 3, 15, 22, 31, Physics, 3, 4, 5, or 3S, 4S, 7.

Secondary Sequences

a) Courses 1, 2, 3, 15, Physics 3S, 4S.

b) Courses 1, 2, 3, 22, Physics 3S, 4S.

GROUPS OF COURSES

Certain Senior College and early graduate courses introductory to the higher mathematics may be grouped for reference as follows: (A) †Differential and integral calculus with applications (3Mjs.); (B) †Solid analytics; selected topics in mathematics; theory of equations; determinants and symmetric functions; limits and series; (C) †Analytic mechanics (2Mjs.); vector analysis; celestial mechanics (2Mjs.); (D) †Synoptic course in advanced mathematics, †differential equations, †theory of definite integrals, elliptic integrals, Fourier series and Bessel functions, elements of the theory of functions; (E) Synthetic projective geometry; analytic projective geometry; metric differential geometry; projective

differential geometry; (F) Theory of numbers; theory of invariants; selected chapters of algebra; theory of substitutions with applications to algebraic equations.

NOTE.—The courses marked † are given annually; the other courses usually once in two years.

These courses and the special courses in the Higher Mathematics are intended to give the student a comprehensive view of modern mathematics, to develop him to scientific maturity, and to enable him to follow, without further guidance, the scientific movement of the day in mathematics, and, if possible, to take an active part in it by creative research.

The special and research courses vary from year to year. They may be classified, in general, as relating to (*a*) Algebra and Arithmetic; (*b*) Analysis; (*c*) Geometry; (*d*) Mechanics and Applied Mathematics; and (*e*) the Foundations and Interrelations of the Mathematical Disciplines as purely abstract deductive systems. Courses of type (*d*) are also offered by the Departments of Astronomy and Physics.

PREPARATION FOR TEACHING

Courses in the history and the teaching of Elementary Mathematics—Arithmetic, Algebra, Geometry, Trigonometry, Analytic Geometry, Calculus, Mechanics—are offered by this Department and the School of Education. These courses embody the conviction that elementary students need to have their mathematics made not easier but more perfectly intelligible and attractive.

To this end it is believed that teachers should more generally appreciate and utilize in instruction the unity of mathematics, as made up of various closely interrelated parts, and the character of mathematics, as an ideal science developed by abstraction from various more concrete domains.

A) *Secondary-school positions.*—Students who expect to teach mathematics as a major subject in secondary schools should complete at least the following courses in their undergraduate career: (1) Courses in pure mathematics: Trigonometry, College Algebra, Plane Analytic Geometry, Differential and Integral Calculus and Applications of Calculus, Theory of Equations, and the Synoptic course; (2) Courses in applied mathematics: Descriptive Astronomy, Mechanics, and General Physics; (3) The two courses, Principles of Education and Methods of Education, which may be taken either in the Junior College or in the Senior College; (4) Practice Teaching in Mathematics in the University High School, for which the foregoing courses in education are prerequisite; (5) A course in the Teaching of Secondary Mathematics and a course in the History of Secondary Mathematics.

B) *Minor collegiate positions.*—Those who look forward to teaching mathematics in normal schools and small colleges should as undergradutes complete at least the following courses: (1) The general courses in education and those in the history and teaching of mathematics mentioned in (3) and (5) above; (2) The content courses specified in (1) and (2) above, together with Advanced Calculus (3 majors).

Candidates for these positions should take at least one year of graduate work leading to the Master's degree in Mathematics and during this year should visit some of the college courses in Mathematics with the purpose of observing methods of teaching.

C) *University positions.*—Candidates for university positions should qualify for the Doctor's degree. Courses in the history of mathematics and in the principles and practices of education are strongly recommended.

HIGHER DEGREES

Master's degree.—Candidates for the Master's degree in Mathematics are expected, on the basis of a principal sequence of nine majors of undergraduate mathematics, to offer for examination eight approved courses of groups (A)–(E), including the elements of the theory of functions, and to present a satisfactory dissertation on an assigned topic closely related to the subject of one of the courses.

Degree of Doctor of Philosophy.—Candidates for the Doctor's degree with Mathematics as secondary subject are expected to offer for examination nine approved courses in advance of course 3.

Candidates for the Doctor's degree with Mathematics as principal subject are expected (1) to offer for examination the subjects covered by fifteen majors of initial courses of groups (B)–(F), including two of each of the types (*a*)–(*e*), and by a considerable body of special courses, in each case presumably most closely related to the subject of the doctoral dissertation, and (2) to present a dissertation, in finished form, embodying valuable results of mathematical inquiry. The subject of the dissertation may be a topic of pure or applied mathematics or of the history, philosophy, or pedagogy of mathematics.

MISCELLANEOUS INFORMATION

Clubs.—The Departmental Club meets fortnightly for the review of memoirs and books, and for the presentation of results of research. The club is conducted by the members of the Faculties of Mathematics and Mathematical Astronomy. Graduate students of the Departments are expected to attend and otherwise to participate in the meetings of the club.

The Junior Mathematical Club, with fortnightly meetings, is conducted by the graduate students of the Departments of Mathematics and of Astronomy and Astrophysics. It is open to undergraduates majoring in Mathematics.

Library.—The library contains the more important works on mathematics (about 7,400 volumes) and has current issues and complete files of the leading periodicals.

Models.—The collection of models includes a set of Brill's models: plaster and thread models of quadric surfaces, plaster models of cubic and Kummer's quartic surfaces, models of cyclides and surfaces of constant positive and negative curvature, and thread models of three-dimensional projections of four-dimensional regular bodies.

Summer Quarter.—The courses of the Summer Quarter are planned with special reference to the needs of those who are able to spend only the summer in residence. The courses are arranged so as to enable the student to continue his work progressively in successive summers, and so that the courses of four consecutive summers give a wide view of modern mathematics. The student who is obliged to leave before the close of the Summer Quarter may usually arrange to complete his work by correspondence.

Scholarship Examinations.—The competitive examinations for the Senior College Scholarships and for the Graduate Scholarship in Mathematics are held

each Spring Quarter at times and places announced in the *Weekly Calendar*. Prospective candidates should confer with the Departmental Examiner in Mathematics.

COURSES OF INSTRUCTION

For the time schedule of courses in Mathematics, see page 22.

I. JUNIOR COLLEGE COURSES

1. Plane Trigonometry.—Mj. Summer, Professor Gingrich; Autumn, 3 sections, Associate Professor Laves; ——— and ———; Winter, 2 sections, ——— and ———; Spring, 2 sections, Professor Slaught and Associate Professor Laves.

2. College Algebra.—Prerequisite course 1. Mj. Summer, Professor Wilczynski; Autumn, 2 sections, Associate Professor Young and Dr. Logsdon; Winter, 2 sections, ——— and ———; Spring, Associate Professor Young.

3. Plane Analytic Geometry.—Elements of plane analytics, including the geometry of the conic sections, with an introduction to solid analytics. Prerequisite: course 1. Mj. Summer, Mr. Vandiver; Autumn, Associate Professor Young; Winter, 2 sections, Associate Professor Laves and Dr. Logsdon; Spring, Professor Moore.

4A. Surveying (Astronomy 4A).—Prerequisite: course 1. Mj. Spring, Associate Professor Laves.

5. Spherical Trigonometry with Applications to Astronomy (Astronomy 2).—Prerequisite: course 1. Mj. Winter, Associate Professor Laves.

II. SENIOR COLLEGE COURSES

15. Introductory Calculus for Students of Science.[1]—The elementary fundamental principles, methods, and formulas of differential and integral calculus; applications to simple problems of geometry and the physical sciences. This course is intended primarily for students of physics and chemistry who do not wish to take the longer course in Calculus (courses 18, 19, and 20). Prerequisite: course 1 and course 2 or course 3. [Not given in 1922–23.]

18, 19, 20. Calculus I, II, III.—A development of the three fundamental notions of the Calculus: the derivative, the anti-derivative, the definite integral, with especial emphasis on their geometric interpretations and their relations to problems in geometry, mechanics, and physics. Prerequisite: courses 1, 2, and 3. Three consecutive majors. 2 sections, Autumn, Professor Slaught; Winter and Spring, Professor Bliss; Autumn, Winter, Spring, Dr. Logsdon.

18, 19. Calculus I, II.—Prerequisite: courses 1, 2, and 3. Two consecutive majors. Winter and Spring, Professor Wilczynski.

18. Calculus I: Differential Calculus.—Derivatives; maxima and minima; curve tracing; Maclaurin's and Taylor's Series; indeterminate forms; partial derivatives; applications to geometry and physics. Prerequisite: courses 1 and 3 unless 3 is taken simultaneously. Mj. Summer, Associate Professor Young.

19. Calculus II: Integral Calculus.—A course aimed at a comprehension of the nature of integration and of its applications to geometry and physics; solution of numerous problems; use of table of integrals. Prerequisite: course 18. Mj. Summer, Associate Professor R. L. Moore.

22. Elementary Theory of Equations.—Numerical equations, determinants and symmetric functions. Text: Dickson's *First Course in Theory of Equations*. Prerequisite: Differential Calculus. Mj. Summer, Associate Professor Young; Autumn, Professor Dickson.

23. Solution of Numerical Equations.—[Not given in 1922–23.]

[1] If a student has credit for course 15, credit will be given for course 18 only in case the latter is completed with the standing of B – or better.

24. Determinants and Symmetric Functions.—[Not given in 1922–23.]

24A. Determinants.—[Not given in 1922–23.]

27. Units and Dimensions.—A study of the basic mathematical aspects of physical science. Primarily a survey of those experimental relations in mechanics, heat, and electromagnetism which involve universal constants, with the ensuing theory of derived units, dimensions, and similitude. In connection with illustrative problems some attention is given to methods of computation and the reduction of observations. Prerequisite: Calculus and General Physics. Mj. Autumn, Associate Professor Lunn.

28. Selected Topics in Mathematics.—Associate Professor Young. [Not given in 1922–23.]

29, 30. Projective Geometry I, II.—Two consecutive majors. Professor Wilczynski. [Not given in 1922–23.]

31. Solid Analytic Geometry.—Co-ordinate geometry of curves and surfaces in three-dimensional space, in particular, those of the first and the second degree. Prerequisite: Courses 3, 18, and the equivalent of 22. Mj. Winter, Professor Dickson.

34. Limits and Series.—Definitions and fundamental properties of various types of limits. Prerequisite: Differential and Integral Calculus. M. Summer, First Term, Professor Moore; Mj. Spring, Associate Professor Young.

Mathematics in the Grades (School of Education; Math. 1).—Mj. Winter, Professor Myers.

Mathematics in the Lower Grades (School of Education; Math. 1A).—M. Summer, First Term, Professor Myers.

Mathematics for Grades VII–IX (School of Education; Math. 1B).—M. Summer, Second Term, Professor Myers.

The Teaching of Secondary Mathematics (School of Education; Math. 2).—Mj. Autumn, Assistant Professor Breslich; Mj. Spring, Professor Myers.

The Teaching of Secondary Mathematics (School of Education; Math. 2A).—M. Summer, First Term, Professor Myers; repeated M. Second Term, Assistant Professor Breslich.

The Teaching of Secondary Mathematics (School of Education; Math. 2B).—M. Summer, First Term, Assistant Professor Breslich; repeated M. Second Term, Professor Myers.

History of Mathematics (School of Education; Math. 5).—Mj. Winter, Professor Myers.

37. Critical Review of Secondary Mathematics.—Mj. Associate Professor Young. [Not given in 1922–23.]

38. Synoptic Course in Advanced Mathematics.—Mj. Professor Wilczynski. [Not given in 1922–23.]

Analytic Mechanics I, II (Astronomy 5, 6).—An introductory course. Prerequisite: Mathematics 18, 19. 2Mjs. Autumn, Professor Gale; Winter, Associate Professor MacMillan.

40. Topics of Geometry.—Associate Professor Young. [Not given in 1922–23.]

47. Differential Equations.—A study of the more common types of ordinary differential equations, especially those of the first and second orders, with emphasis on geometrical interpretations and applications to geometry, elementary mechanics, and physics. Prerequisite: courses 18, 19, and preferably 20. Mj. Summer and Autumn, Professor Slaught.

48. Theory of Definite Integrals.—A course treating of the properties and methods of computing definite integrals, including a study of methods of approximation, improper definite integrals, Eulerian integrals, multiple integrals, with many problems and applications. Prerequisite: course 47. Mj. Winter, Professor Bliss.

49. Elliptic Integrals.—A systematic development of the theory of indefinite integration, leading to elliptic integrals and the elements of elliptic functions, with attention to problems and applications. This course includes also an introduction to Fourier series. Prerequisite: courses 18, 19, 20, and preferably 48. Mj. Summer and Spring, PROFESSOR SLAUGHT.

50. Fourier Series and Bessel Functions.—Mj. ASSOCIATE PROFESSOR LUNN. [Not given in 1922–23.]

60. Synoptic Course in the Theory of Numbers.—Mj. PROFESSOR DICKSON. [Not given in 1922–23.]

III. GRADUATE COURSES

NOTE.—Students should register for graduate courses only after consultation with instructors.

65–69. Reading and Research in Mathematics.—If in the judgment of the Department it is advisable that a student undertake definite mathematical reading and research not closely connected with any current lecture course or seminar, he will register for one of the following informal courses 65–69.

65. Reading and Research in Foundations of Mathematics and in General Analysis.—Mj. or DMj. PROFESSOR MOORE.

66. Reading and Research in Algebra and the Theory of Numbers.—Mj. or DMj. PROFESSOR DICKSON.

67. Reading and Research in Analysis.—Mj. or DMj. PROFESSOR BLISS.

68. Reading and Research in Geometry.—Mj. or DMj. PROFESSOR WILCZYNSKI.

69. Reading and Research in Applied Mathematics.—Mj. or DMj. ASSOCIATE PROFESSOR LUNN.

Advanced Mechanics (Astronomy 21).—Prerequisite: Astronomy 5, 6. Mj. Autumn, ASSOCIATE PROFESSOR MACMILLAN.

Celestial Mechanics I (Astronomy 22).—An introductory course. Pre requisite: Mathematics 18, 19, and Analytic Mechanics I and II. Mj. Spring, ASSOCIATE PROFESSOR MACMILLAN.

71. Theory of Numbers I.—Introductory course. Theory of congruences, the quadratic reciprocity theorem, and the theory of quadratic forms. Mj. Autumn, PROFESSOR DICKSON.

72. Theory of Numbers II.—Advanced course with prerequisite 71. Mj. Winter, PROFESSOR DICKSON.

74. Theory of Algebraic Numbers.—Prerequisite: course 71. Mj. PROFESSOR DICKSON. [Not given in 1922–23.]

75. Topics in the Theory of Numbers.—After suitable development of the necessary foundations, the course will lead into the theory of cyclotomic fields and the higher laws of reciprocity. Mj. Summer, MR. VANDIVER.

81. Substitution Groups and Algebraic Equations.—Mj. PROFESSOR DICKSON. [Not given in 1922–23.]

82. Finite Groups.—Mj. PROFESSOR DICKSON. [Not given in 1922–23.]

84. Continuous Groups.—Mj. PROFESSOR DICKSON. [Not given in 1922–23.]

91. Introduction to Higher Algebra.—Mj. PROFESSOR DICKSON. [Not given in 1922–23.]

93. Theory of Algebraic Invariants.—An introduction to the non-symbolic theory of invariants of binary forms, with applications to geometry, followed by an explanation of the symbolic notation, with practice in its use. Based on Dickson's *Algebraic Invariants*. Mj. Spring, DR. LOGSDON.

94. Modern Higher Algebra.—Especially theory of matrices, bilinear and quadratic forms. Mj. PROFESSOR DICKSON. [Not given in 1922–23.]

98. Linear Algebras.—An introduction to the theory of hypercomplex numbers, with attention to quaternions, the relations of the theory to matrices, bilinear forms, and groups. Text: Dickson's *Linear Algebras*, 1914, Cambridge Tracts on Mathematics and Mathematical Physics. Mj. Autumn, 1923, PROFESSOR DICKSON.

100. Fundamental Number Systems of Analysis.—Synthetic determination (from the system of integers 1, 2, 3, . . .) and study of the elementary properties of the systems of all (1) rational integers, (2) rational numbers, (3) real numbers, (4) ordinary complex numbers, and (5) quaternions. For graduate students. M. Summer, First Term, PROFESSOR MOORE.

101. Theory of Functions of a Real Variable.—Mj. PROFESSOR BLISS. [Not given in 1922–23.]

102. Ordinary Linear Differential Equations of the Second Order.—Mj. PROFESSOR BLISS. [Not given in 1922–23.]

104. Calculus of Variations.—Examples illustrating the various types of problems. The differential equations of a curve which minimizes a definite integral in a space of two or more dimensions. Other properties of a minimizing curve as deduced by Legendre, Weierstrass, and Jacobi for the case of the plane. Conditions which insure the existence of a minimum. Isoperimetric problems and the more general problems of Lagrange and Mayer. An introduction to the theory of double integrals. Prerequisite: course 101. Mj. Summer, PROFESSOR BLISS.

105. Functions of Lines.—Mj. PROFESSOR BLISS. [Not given in 1922–23.]

106. Partial Differential Equations.—Mj. PROFESSOR BLISS. [Not given in 1922–23.]

108. Differential Equations from the Standpoint of Lie.—Mj. PROFESSOR BLISS. [Not given in 1922–23.]

111. Vectors, Matrices, and Quaternions.—The elementary algebraic theory of the subjects specified, as preliminary to Courses 112–115. Open to first-year graduate students. Mj. Autumn, PROFESSOR MOORE.

112, 113, 114, 115. Hermitian Matrices of Positive Type in General Analysis, I, II, III, IV.—A generalization of Hilbert's theory of limited bilinear and quadratic forms in infinitely many variables. For second-year, or more advanced graduate students. Four consecutive majors. I, II, Winter, Spring; III, IV, Autumn, Winter, PROFESSOR MOORE.

121. Theory of Functions of the Complex Variable.—Introduction to the algebra and calculus of complex numbers and their geometric representation; conform representation. The theory of power series and the properties of analytic functions. Introduction to the theory of Riemann surfaces. Prerequisite: courses 47 and 48. Mj. Summer, PROFESSOR BLISS; Autumn, ———.

122. Algebraic Functions.—Mj. PROFESSOR BLISS. [Not given in 1922–23.]

123. Elliptic Functions.—Elliptic integrals and the Weierstrassian theory of elliptic functions. Applications of elliptic functions. Mj. Spring, PROFESSOR BLISS.

130. Foundations of Geometry.—Mj. PROFESSOR MOORE. [Not given in 1922–23.]

131. Foundations of Analysis Situs.—Sets of postulates for plane analysis situs. Fundamental properties of point-sets (and collections of point-sets) of various types, including continuous curves, equi-continuous systems of curves, etc. For graduate students. Prerequisite: A certain degree of mathematical maturity. Mj. Summer, ASSOCIATE PROFESSOR R. L. MOORE.

141. Analytic Projective Geometry.—Mj. PROFESSOR WILCZYNSKI. [Not given in 1922–23.]

142. Higher Plane Curves.—Mj. PROFESSOR WILCZYNSKI. [Not given in 1922–23.]

144. Line Geometry.—Mj. PROFESSOR WILCZYNSKI. [Not given in 1922–23.]

145. Higher Geometry.—Mj. PROFESSOR WILCZYNSKI. [Not given in 1922–23.]

151. Metric Differential Geometry.—Mj. PROFESSOR WILCZYNSKI. [Not given in 1922–23.]

154, 155. Projective Differential Geometry I, II.—These courses give a brief account of Lie's theory, with applications to the theory of invariants of systems of linear differential equations. The projective differential properties of plane and space curves, of surfaces and congruences, then present themselves as a result of interpreting this invariant theory geometrically. Text: Wilczynski's *Protective Differential Geometry of Curves and Ruled Surfaces.* (B. G. Teubner, Leipzig, 1906.) Prerequisite: an elementary knowledge of differential equations and projective geometry. Two consecutive majors, Winter, Spring, PROFESSOR WILCZYNSKI.

156. Theory of Plane Curves.—Mj. PROFESSOR WILCZYNSKI. [Not given in 1922–23.]

157. Theory of Ruled Surfaces and Space Curves.—Mj. PROFESSOR WILCZYNSKI. [Not given in 1922–23.]

158. Theory of Surfaces and Congruences.—Mj. PROFESSOR WILCZYNSKI. [Not given in 1922–23.]

160. Vector Analysis.—The elements of vector algebra, vector differentiation and integration, and the linear vector function; illustrated by typical applications to geometry, mechanics, and physics. Prerequisite: courses 31 and 48. Mj. Summer, ASSOCIATE PROFESSOR LUNN.

162. Applications of Vector Analysis in the Theory of Electromagnetism.—Mj. ASSOCIATE PROFESSOR LUNN. [Not given in 1922–23.]

163. Theory of Attraction and the Potential.—Mj. ASSOCIATE PROFESSOR LUNN. [Not given in 1922–23.]

164. Dynamics of Oscillatory Systems: Theory of Sound.—Mj. ASSOCIATE PROFESSOR LUNN. [Not given in 1922–23.]

165. Thermodynamics.—The relations of thermal and mechanical processes, measurement of heat energy and entropy, the thermodynamic scale of temperature, and application of the general laws to particular physical systems. Thermodynamic potentials and introduction to Gibbs's theory of chemical equilibrium. Mj. Winter, ASSOCIATE PROFESSOR LUNN.

166. Dynamics of Continuous Media.—Kinematics of continuous media and dynamical theory of typical forms of motion in perfect and viscous fluids; geometry of strain and dynamical relations of stress and strain, with selected problems in the equilibrium and motion of elastic solids. Mj. Autumn, ASSOCIATE PROFESSOR LUNN.

168. Canonical Equations and Quantum Theory.—A survey of the Lagrange-Hamilton-Jacobi theory of the equations of dynamics, including their recent applications in statistical mechanics and quantum theory. Mj. Winter, ASSOCIATE PROFESSOR LUNN.

170. Statistics and Probability.—The theory of average and probability for finite and infinite sets of elements; the statistical treatment of observations and the method of least squares; introduction to statistical mechanics, with examples from the theories of molecules and electrons. Prerequisite: Differential Equations. Mj. Summer, ASSOCIATE PROFESSOR LUNN.

171. Statistical Mechanics.—Mj. ASSOCIATE PROFESSOR LUNN. [Not given in 1922–23.]

172. Partial Differential Equations of Mathematical Physics; the Conduction of Heat.—Mj. ASSOCIATE PROFESSOR LUNN. [Not given in 1922–23.]

178, 179. Relativity and the Theory of Gravitation.—ASSOCIATE PROFESSOR LUNN. [Not given in 1922–23.]

181, 182, 183. Seminar on Foundations of Mathematics and General Analysis I, II, III.—Three consecutive majors. PROFESSOR MOORE. [Not given in 1922–23.]

184. Seminar on Algebra and the Theory of Numbers.—Mj. PROFESSOR DICKSON. [Not given in 1922–23.]

TABULAR VIEW OF COURSES OFFERED BY THE DEPARTMENT OF MATHEMATICS, 1922–23

Junior College courses are in italics; Senior College courses in capitals; Graduate courses in Roman type

Hour	Summer, 1922	Autumn, 1922	Winter, 1923	Spring, 1923
8:00	49. ELLIPTIC INTEGRALS (Slaught) 100. Fundamental Number Systems of Analysis M. 1st T. (E. H. Moore)	2a. *College Algebra* (Logsdon) 47. DIFFERENTIAL EQUATIONS (Slaught) Ast. 51. Analytic Differential Equations I (Moulton) 121. Functions of a Complex Variable (———)	1a. *Plane Trigonometry* (———) 48. DEFINITE INTEGRALS (Bliss) Ast. 52. Analytic Differential Equations II (Moulton) 168. Canonical Equations and Quantum Theory (Lunn)	49. ELLIPTIC INTEGRALS (Slaught) Ast. 53. Analytic Differential Equations III (Moulton)
9:00	1. *Plane Trigonometry* (Gingrich) 47. DIFFERENTIAL EQUATIONS (Slaught) 121. Functions of a Complex Variable (Bliss)	Ast. 5. ANALYTIC MECHANICS I (Gale) Ast. 21. Advanced Mechanics (MacMillan) 18a. CALCULUS I (Slaught) 111. Vectors, Matrices, and Quaternions (Moore)	Ast. 6. ANALYTIC MECHANICS II (MacMillan) 19a. CALCULUS II (Bliss) 112. Matrices in General Analysis I (Moore) 165. Thermodynamics (Lunn)	Ast. 22. Celestial Mechanics I (MacMillan) 20a. CALCULUS III (Bliss) 113. Matrices in General Analysis II (Moore)
10:00	2. *College Algebra* (Wilczynski) 34a. LIMITS M. 1st T. (E. H. Moore) 104. Calculus of Variations (Bliss) 160. Vector Analysis (Lunn)	1a. *Plane Trigonometry* (———) 18b. CALCULUS I (Logsdon) 71. Theory of Numbers I (Dickson)	2a. *College Algebra* (———) 19b. CALCULUS II (Logsdon) 72. Advanced Theory of Numbers (Dickson)	1a. *Plane Trigonometry* (Slaught) 20b. CALCULUS III (Logsdon) 123. Elliptic Functions (Blis)
11:00	151. Metric Differential Geometry (Wilczynski) 170. Statistics and Probability (Lunn)	22. THEORY OF EQUATIONS (Dickson) 114. Matrices in General Analysis III (Moore)	1b. *Plane Trigonometry* (———) 3a. *Plane Analytics* (Logsdon) 31. SOLID ANALYTICS (Dickson) 115. Matrices IV (Moore)	3. *Plane Analytic Geometry* (Moore) 93. Theory of Algebraic Invariants (Logsdon)
12:30		2b. *College Algebra* (Young)		1b. *Plane Trigonometry* (Laves) 2. *College Algebra* (Young)
1:30	3. *Plane Analytic Geometry* (Vandiver) 18. DIFFERENTIAL CALCULUS (Young) Ast. 22. Celestial Mechanics (Moulton) 131. Foundations of Analysis Situs (R. L. Moore)	1b. *Plane Trigonometry* (———) 3. *Plane Analytic Geometry* (Young) 27. UNITS AND DIMENSIONS (Lunn)	2b. *College Algebra* (———) Ast. 2. *Spherical Trigonometry* (Laves) 154. Projective Differential Geometry I (Wilczynski)	Ast. 4A. *Introduction to Surveying* 1:30–3:30 (Laves) 34. LIMITS AND SERIES (Young) 155. Projective Differential Geometry II (Wilczynski)
2:30	19. INTEGRAL CALCULUS (R. L. Moore) 22. THEORY OF EQUATIONS (Young) 75. Theory of Numbers	1c. *Plane Trigonometry* (Laves) 166. Dynamics of Continuous Media (Lunn)	3b. *Plane Analytic Geometry* (Laves) 18. CALCULUS I (Wilczynski)	19. CALCULUS II (Wilczynski)

THE DEPARTMENT OF ASTRONOMY AND ASTROPHYSICS

OFFICERS OF INSTRUCTION

Edwin Brant Frost, A.M., Sc.D., Professor of Astrophysics; Director of the Yerkes Observatory.

Edward Emerson Barnard, A.M., Sc.D., LL.D., Professor of Practical Astronomy at the Yerkes Observatory.

Forest Ray Moulton, Ph.D., Professor of Astronomy.

Kurt Laves, Ph.D., Associate Professor of Astronomy.

William Duncan MacMillan Ph.D., Associate Professor of Astronomy.

John Adelbert Parkhurst, S.M., Associate Professor of Practical Astronomy at the Yerkes Observatory.

Storrs Barrows Barrett, A.B., Assistant Professor of Astrophysics; Secretary and Librarian of the Yerkes Observatory.

George Van Biesbroeck, Dr.Eng., Assistant Professor of Practical Astronomy at the Yerkes Observatory.

Oliver Justin Lee, S.M., Ph.D., Instructor in Practical Astronomy at the Yerkes Observatory.

Otto Struve, Diploma of 1st Class, University of Kharkov, Assistant in Stellar Spectroscopy.

FELLOW, 1921–22

Horace Clifford Levinson, A.B.

VOLUNTEER RESEARCH ASSISTANTS

Harriet W. Bigelow, Ph.D., Professor of Astronomy, Smith College (Summer, 1922).

Alice Farnsworth, Ph.D., Instructor in Astronomy, Mount Holyoke College (Summer, 1922).

INTRODUCTORY

The work of the Department of Astronomy and Astrophysics is divided into two parts:

(1) Work at the University, comprising: (*a*) elementary instruction in general Astronomy, both theoretical and practical; (*b*) preliminary training in the principles and methods of work underlying the science of Astrophysics (given in part in the Department of Physics); (*c*) graduate and research work in Celestial Mechanics.

(2) Graduate and research work in Practical Astronomy and Astrophysics in the Yerkes Observatory at Williams Bay, Wisconsin.

At the University, in the work given by Professor Moulton, Associate Professor Laves, and Associate Professor MacMillan, emphasis will be laid on the development of the mathematical principles and methods which form the basis of the physical sciences. In addition to the courses in Descriptive Astronomy, Introduction to Celestial Mechanics, and Analytic Mechanics, courses in Periodic Orbits and in the various other branches of Celestial Mechanics will be given within periods not exceeding three years. The most fundamental subjects will be arranged so as to recur at regular intervals, while other more special topics will vary from time to time. The general object of the instruction will be to give

experience and preliminary training in the work of observation and reduction; to furnish the student an adequate mathematical basis for successful work in Celestial Mechanics, and to direct research work in Celestial Mechanics. The Departmental Club meets fortnightly for the review of memoirs and books and for the presentation of results of research. The club is conducted by the members of the Faculties of Mathematics and Mathematical Astronomy. Graduate students of Mathematical Astronomy are expected to attend regularly and, so far as possible, to participate actively in the meetings of the club.

At the Yerkes Observatory the advanced student is made familiar with modern methods of research in various branches of Practical Astronomy and Astrophysics. The rapid development of the latter science within the last two decades has been fully recognized in the equipment of the Observatory; the special laboratory facilities makes some investigations possible which cannot be carried on where the equipment is less complete. In general, the work in progress during the year 1922–23 will include: researches in solar physics with the spectroscope, spectroheliograph, and photoheliograph; micrometric observations of double stars, planets, satellites, nebulae, and comets; studies of photographic stellar spectra and determinations of motions in the line of sight; photography of stars, comets, nebulae, etc.; photographic investigations of stellar parallax; research in visual and photographic photometry; special astrophysical researches. The opportunity in taking part in these investigations is deemed of more advantage to the qualified student than set courses of instruction; but regular programs of work, with courses of collateral reading, will be laid out as conditions require. During the Summer Quarter illustrated lectures particularly intended for graduate students are given by members of the staff. The Astronomical Club also meets at intervals for the discussion of assigned topics in Astronomy and Astrophysics.

FACILITIES

For instruction in Practical Astronomy a students' observatory is maintained. It is equipped with a modern Warner & Swasey equatorial telescope of 6½ inches aperture, which is provided with a filar micrometer, a 5-inch refractor, a 3-inch Bamberg transit instrument, a Bamberg universal instrument, a Riefler sidereal clock, a chronometer, and various smaller accessories. The laboratory courses offered by the Department of Physics afford excellent preliminary training for the work in Astrophysics.

For a description of the Yerkes Observatory, see the *Annual Register* of the University of Chicago, Part V of this volume. An illustrated pamphlet of 24 pages, describing the observatory in detail, may be obtained on application.

DEGREES

The Master's degree.—Students working for a Master's degree in Astronomy are advised to choose three majors of graduate work in the Department of either Mathematics or Physics and six majors in the Department of Astronomy from courses numbered 5 to 10, 22, and 23. Those working for the Master's degree in Practical Astronomy or Astrophysics at the Yerkes Observatory are not required to spend part of their time at the University, although this is advised where possible.

The Degree of Doctor of Philosophy.—The courses prescribed for the Master's degree together with three other graduate courses will meet the requirement for the Doctor's degree where Astronomy is the minor subject.

Candidates for the Doctor's degree, with Astronomy as major subject, are expected to take a number of courses in Mathematics and Physics. Students intending to specialize in Mathematical Astronomy will be required to take Advanced Integral Calculus, Differential Equations, and Theory of Functions of a Complex Variable; students intending to specialize in the lines of Astrophysics will be required to take the work in Theoretical Physics, Advanced Experimental Physics, Sound and Light, and Physical Manipulation. The courses in Astronomy which will be required depend on the phase of the subject which the candidate elects for his work. Students specializing in Mathematical Astronomy are expected to spend six months at the Yerkes Observatory, and those working in Practical Astronomy and Astrophysics are expected to spend at least two quarters at the University.

COURSES AVAILABLE FOR UNDERGRADUATES

SEQUENCES

3A and B, Descriptive Astronomy; 2, Spherical Trigonometry, with applications; 5, 6, Analytic Mechanics; 7A and B, Practical Astronomy; 10, Spectroscopy and Astrophysics; 22, 23, Celestial Mechanics; Mathematics 3, Analytic Geometry; 18, 19, Calculus; Physics 3, Mechanics, Molecular Physics, Heat; 4, Electricity, Sound, and Light.

The Department offers no nine-major sequences.

SECONDARY SEQUENCES

I. Astronomy

Courses 2, 3A, 3B, 7A, 7B, 10.

II. Astronomy and Mathematics

Courses 3, 18, 19, in Mathematics, 5, 6, 22, in Astronomy.

III. Astronomy and Physics

Courses 3A, 3B, Physics 3, 4, Astronomy 7, 10.

COURSES OF INSTRUCTION

I. JUNIOR COLLEGE COURSES

1. Descriptive Astronomy (shorter course).—An elementary course, dealing with fundamental facts, principles, and methods. Frequent access to the students' observatory. Mj. Summer, 2:30, PROFESSOR MOULTON; Autumn, 9:00, PROFESSOR MOULTON; Spring, 9:00, PROFESSOR MOULTON; 10:00, ASSOCIATE PROFESSOR MACMILLAN.

2. Spherical Trigonometry with Applications to Astronomy and Geodesy.—Mj. Winter, 1:30, ASSOCIATE PROFESSOR LAVES.

3A and 3B. Descriptive Astronomy (longer course; 1 not prerequisite).—A two-quarter course dealing with the fundamental facts and principles of Astronomy. Modern as well as classical methods and results are brought into full discussion. The observational side of the subject also is emphasized. Prerequisite: Plane Trigonometry. 2Mjs. Autumn and Winter, 10:00, ASSOCIATE PROFESSOR MACMILLAN.

4A. Surveying (Mathematics 4A).—Mj. Spring, 1:30–3:30, ASSOCIATE PROFESSOR LAVES.

II. SENIOR COLLEGE COURSES

5. Analytic Mechanics (Statics).—An introductory course. Prerequisite: Mathematics 18, 19. Mj. Autumn, 9:00, PROFESSOR GALE.

6. Analytic Mechanics (Dynamics).—Prerequisite: Mathematics 18, 19. Mj. Winter, 9:00, ASSOCIATE PROFESSOR MACMILLAN.

7. Spherical and Practical Astronomy.—Determination of time, latitude,

and longitude. Prerequisite: Astronomy 1 and Mathematics 3. Mj. Summer, 8:00 P.M., PROFESSOR GINGRICH.

8. Practical Astronomy I.—Observations of binary stars and determination of their orbits. Mj. Spring, 7:30 P.M., ASSOCIATE PROFESSOR LAVES.

9. Practical Astronomy II.—Observation of satellites and determination of orbits of satellites. Mj. Autumn, 7:00 P.M., ASSOCIATE PROFESSOR LAVES.

10. Spectroscopy and Astrophysics (Physics 24).—A non-technical treatment of the growth of Spectroscopy, with applications to solar and stellar phenomena. [Not given in 1922–23.]

III. GRADUATE COURSES

12. The Sidereal Universe.—Prerequisite: Astronomy 1. Mj. Winter, 9:00, PROFESSOR MOULTON.

21. Advanced Mechanics.—Prerequisite: Astronomy 5, 6. Mj. Autumn, 9:00, ASSOCIATE PROFESSOR MACMILLAN.

22. Introduction to Celestial Mechanics I.—Gravitational theory of sun's heat, central forces, potential and attraction of finite bodies, properties of conic section motion. Prerequisite: Mathematics 18, 19. Mj. Summer, 1:30, PROFESSOR MOULTON; Spring, 9:00, ASSOCIATE PROFESSOR MACMILLAN.

23. Introduction to Celestial Mechanics II.—Determination of orbits, special cases of the problems of three bodies: the Lunar Theory geometrically considered; variation of the elements and absolute perturbations. Mj. [Not given in 1922–23.]

31–36. Research Courses at the Yerkes Observatory.—The Yerkes Observatory is open only to graduate students who have completed the necessary preliminary studies and have had the requisite experience in practical laboratory and observatory work. Students wishing to work at the Observatory should first consult the Director of the Yerkes Observatory, Williams Bay, Wis., and obtain his approval. DMj. or 3Mjs. each Quarter, PROFESSORS AND INSTRUCTORS resident at Yerkes Observatory.

41. Theory of Planetary Motion.—Prerequisite: Astronomy 22 and 23. Mj. PROFESSOR MOULTON. [Not given in 1922–23.]

42. The Lunar Theory.—Prerequisite: Astronomy 22 and 23, Mathematics 121. Mj. PROFESSOR MOULTON. [Not given in 1922–23.]

43. Application of the Methods of Periodic Orbits to the Lunar Theory.—Prerequisite: Astronomy 42. Mj. PROFESSOR MOULTON. [Not given in 1922–23.]

44, 45, 46. Exterior Ballistics.—Mj. Autumn, Winter, Spring, 11:00.

47, 48, 49. Advanced Ballistics.—Mj. Autumn, Winter, Spring, 10:00, PROFESSOR MOULTON.

51, 52, 53. Modern Theories of Analytic Differential Equations with Applications to Celestial Mechanics and Periodic Orbits I, II, III.—Properties of the solution of a general system of differential equations of the nth order as functions of the independent variable, of the parameters, of the initial values of the dependent variables. Solutions developed as power series in the independent variable, in the parameters, in the initial values of the dependent variables, by the Cauchy-Lipschitz process, by the Picard approximation process, by continued variation of parameters. Applications to elliptic and hyperelliptic functions and to periodic solutions of the problem of three bodies. Linear equations with applications to hypergeometric functions. Linear equations with periodic coefficients. Mj. Autumn, Winter, Spring, 8:00, PROFESSOR MOULTON.

60. Periodic Solutions of the Problem of Three Bodies.—Mj. PROFESSOR MOULTON. [Not given in 1922–23.]

70. Theory of Figures of Equilibrium of Rotating Fluid Bodies.—This is an advanced course, including Poincaré's and Darwin researches. Mj. PROFESSOR MOULTON. [Not given in 1922–23.]

80, 81, 82. The Problem of Three Bodies.—[Not given in 1922–23.]

TABULAR VIEW OF COURSES OFFERED BY THE DEPARTMENT OF ASTRONOMY, 1922–23

Junior College courses are in italics; Senior College courses in CAPITALS; Graduate courses in Roman type

Hour	Summer, 1922	Autumn, 1922	Winter, 1923	Spring, 1923
8:00		51. Modern Theories of Differential Equations I (Moulton)	52. Modern Theories of Differential Equation II (Moulton)	53. Modern Theories of Differential Equations III (Moulton)
9:00		1. *Descriptive Astronomy* (Moulton) 5. ANALYTIC MECHANICS (Gale) 21. Advanced Mechanics (MacMillan)	6. ANALYTIC MECHANICS (MacMillan) 12. Sidereal Universe (Moulton)	1*a*. *Descriptive Astronomy* (Moulton) 22. Celestial Mechanics (MacMillan)
10:00		3A. *Descriptive Astronomy* (MacMillan) 47. Advanced Ballistics (Moulton)	3B. *Descriptive Astronomy* (MacMillan) 48. Advanced Ballistics (Moulton)	1*b*. *Descriptive Astronomy* (MacMillan) 49. Advanced Ballistics (Moulton)
11:00		44. Exterior Ballistics (———)	45. Exterior Ballistics (———)	46. Exterior Ballistics (———)
1:30	22. Celestial Mechanics (Moulton)		2. *Spherical Trigonometry with Applications to Astronomy and Geodesy* (Laves)	4A. *Surveying* 1:30–3:30 (Laves)
2:30	1. *Descriptive Astronomy* (Moulton)			
8:00 P.M.	7. PRACTICAL ASTRONOMY (Gingrich)	9. SATELLITES (Laves)		8. PRACTICAL ASTRONOMY 7:30 P.M. (Laves)

31–36. Research courses at the Yerkes Observatory.

THE DEPARTMENT OF PHYSICS

OFFICERS OF INSTRUCTION

ALBERT ABRAHAM MICHELSON, PH.D., SC.D., LL.D., F.R.S., Professor and Head of the Department of Physics.
HENRY GORDON GALE, PH.D., Professor of Physics.
HARVEY BRACE LEMON, PH.D., Associate Professor of Physics.
ARTHUR JEFFERY DEMPSTER, PH.D., Assistant Professor of Physics.
LLOYD W. TAYLOR, A.B., Instructor in Physics.
FABIAN MILLER KANNENSTINE, S.B., Research Instructor in Physics.
LEONARD B. LOEB, S.B., PH.D., National Research Fellow in Physics.
JOHN PRESTON MINTON, S.B., PH.D., National Research Fellow in Physics.
JARED K. MORSE, S.B., National Research Fellow in Physics.
ALFRED H. FISCHER, A.M., Assistant in Physics.
LAWRENCE E. MCALLISTER, A.B., Assistant in Physics.
FORREST G. TUCKER, A.M., Assistant in Physics.
VERN OLIVER KNUDSEN, A.B., Assistant in Physics.
EDWARD BLANKENSTEIN, S.M., Assistant in Physics.
MARSHALL NEY STATES, A.B., Assistant in Physics.
ROSCOE E. HARRIS, S.B., Assistant in Physics.
EDWARD STOWE AKELEY, A.B., Assistant in Physics.
GEORGE SPENCER MONK, S.B., Research Assistant in Physics.
ROBERT ORLAND HUTCHINSON, A.B., Assistant in Physics.

LEIGH PAGE, PH.D., Professor of Physics, Yale University (Summer, 1922).
WILLIAM F. G. SWANN, SC.D., Professor of Physics, University of Minnesota (Summer, 1922).
HAROLD ALBERT WILSON, F.R.S., A.M., SC.B., Professor of Physics, Rice Institute (Summer, 1922).

FELLOWS, 1921–22

JAMES MILTON EGLIN, A.B. WILLIAM VERMILLION HOUSTON, A.B.
WILLIAM SCRIBNER KIMBALL, A.M.

INSTRUCTIONAL WORK

The instructional work in Physics is directed toward the following ends: (1) the training of original investigators in physics; (2) the training of men competent to fill college and university positions as teachers of physics; (3) the training of teachers of physics for secondary schools; (4) the training of pre-engineering and premedical students for later professional work; (5) the training of the general student in scientific methods of work and in the understanding of the place of physical science in the modern world. From the most elementary to the most advanced courses the laboratory and the problem method of instruction are emphasized.

FACILITIES

The Ryerson Physical Laboratory has been enlarged and remodeled with especial reference to offering the best facilities for research work. The entire

lower floor and basement are given up to private research-rooms. A well-equipped shop, with skilled instrument-makers, furnishes opportunity for the construction of special pieces of research apparatus. The equipment has been selected with reference to the needs of research, and includes spectroscopic instruments of highest power, electrical apparatus for work in alternating and direct currents through large ranges of potential, and appliances for high- and for low-temperature work, including a liquid-air plant. The library of the Department is well equipped for research purposes. A Physics Club is conducted by the members of the Department, and meets regularly for the discussion of the results of research work done in the Ryerson Laboratory and elsewhere.

COURSES AVAILABLE FOR UNDERGRADUATE SEQUENCES

3, Mechanics; 4, Electricity; 5, Heat, Sound, and Light; 3S, Mechanics, Molecular Physics, and Heat; 4S, Electricity, Sound, and Light; 7, Lecture Demonstrations in Physics; 9, Elementary Wireless Telegraphy; 11, Heat and Molecular Physics; 12, Light; 13, Electricity and Magnetism; 14, Pedagogy of Physics; 15, Mechanics and Wave-Motion; 16, 17, 18, 19, Experimental Physics; 20, Physical Manipulation; 21, Analytic Mechanics (Astronomy 5, 6); Education 62, Educational Psychology; 1, Principles of Education; Astronomy 3, Descriptive Astronomy (two majors); Mathematics 18, 19, Calculus.

Graduate courses in the Department may be substituted for courses 10 to 19 by students who have the prerequisites.

PRINCIPAL SEQUENCES

a) Courses 3, 4, 5, or 3S, 4S, 7, and any six majors chosen from courses 10 to 13; 15 to 19.

Physics and Mathematics

b) Courses 3, 4, 5, or 3S, 4S, 7, and any six majors from the following: Mathematics 18, 19; Astronomy 5, 6, and Physics 10 to 13; 15 to 19.

Teacher's Sequences

c) Courses 3, 4, 5, or 3S, 4S, 7; three majors from 10 to 13, 16 to 19; 14; Education 62 and Philosophy 7.

Physics and Astronomy

d) Courses Physics 3, 4, 5, or 3S, 4S, 7; Astronomy 3 (two majors), with four majors selected from Physics 10–19, and Mathematics 18, 19.

Physics and Chemistry

e) Courses Physics 3, 4, 5, or 3S, 4S, 7; Chemistry 2S, 3S, and four majors selected from Physics 10–19, and Mathematics 18, 19.

In any of the foregoing sequences graduate courses numbered 31 to 69 may be substituted for courses 10 to 18 by students who have the required prerequisites.

SECONDARY SEQUENCES

a) Courses 3, 4, 5, or 3S, 4S, 7; and three advanced majors in Physics.

b) Courses 3, 4, 5, or 3S, 4S, 7, and three majors from the following: 10 to 69, Astronomy 3, (two majors), Chemistry 2S, 3S; Mathematics 18, 19.

DEGREES

All candidates for the S.B. degree who elect their major work in Physics are required to take courses 3, 4, and 5, and either six majors selected from

courses 10, 11, 12, 13, 15, 16, 17, 18, 19, 24, and 28, or three of these and three Senior College courses in one of the following departments: Mathematics, Astronomy, Chemistry, Geology, or Geography.

The Master's degree.—Candidates for the Master's degree in Physics are required to take eight majors in Physics and related subjects, and to present in addition a dissertation embodying the results of a laboratory problem. Course 7 and all courses in the Department numbered 10 or above, except course 20, will be counted in satisfaction of this requirement, but at least three majors selected from courses 10, 11, 12, 13, and 15 must be included.

The degree of Doctor of Philosophy.—Candidates for the Doctor's degree with Physics as a minor subject must take six of the following courses: 10, 11, 12, 13, 15, 16, 17, 18, 19, 24, 28, and three additional majors of graduate work. When Physics is one of two minor subjects, the courses must be arranged by consultation with the Department.

All candidates for the Doctor's degree with Physics as the major subject must take the following courses: 10, 11, 12, 13, 15, and 28, or their equivalent; three majors selected from courses 16, 17, 18, 19, 37, 38; courses 31–36, and three additional graduate courses selected by the student. Each candidate must also present a dissertation embodying the results of original research in some subject approved by the Department. The time required for the dissertation work generally varies from three to six quarters.

PREPARATION FOR TEACHING

Students preparing to teach Physics in secondary schools are expected to have completed courses 3, 4, 5, 14, and not less than four of courses 10, 11, 12, 13, 15, 16, 17, 18, 19, 24, and 28. See also courses in Physics in the School of Education.

LABORATORY FEE

There is a laboratory fee of $6.00 for all major courses involving laboratory work in the Department of Physics.

COURSES OF INSTRUCTION

I. JUNIOR COLLEGE COURSES

1. Elementary Physics.[1]—A first course in the elements of Physics designed primarily for students who do not present entrance Physics. Prerequisite: Algebra and Plane Geometry, one unit each. DM. Summer, First Term, 1:30–4:30, Mr. McAllister; Mj. Autumn, 3 sections, 8:00–10:00, 10:00–12:00, 1:30–3:30, Mr. Hutchinson, Mr. McAllister, Mr. Harris.

2. Elementary Physics.[1]—A continuation of the preceding course, covering the subjects of electricity, sound, and light. Prerequisite: course 1. DM. Summer, Second Term, 1:30–4:30, Mr. Blankenstein; Mj. Winter, 8:00–10:00, 10:00–12:00, 1:30–3:30, Mr. Hutchinson, Mr. McAllister, Mr. Harris.

3. Mechanics.—A general college course in mechanics presented mainly from the experimental point of view, but including one demonstration lecture each week. Prerequisite: entrance Physics or course 2. Mj. Autumn, 4 sections, 8:00–10:00, 10:00–12:00, 1:30–3:30, 3:30–5:30, Associate Professor Lemon, Mr. Knudsen, Mr. Fischer, Mr. Blankenstein; Winter, 4 sections, 8:00–

[1] Limited-credit course: After a student has credit for 18 majors but less than 27, these courses will be credited at one-half major each; after he has credit for 27 majors they will not be credited at all.

10:00, 10:00–12:00, 1:30–3:30, 3:30–5:30, Associate Professor Lemon, Mr. States, Mr. Akeley, Mr. Taylor, Mr. Blankenstein.

4. Electricity.—A general college course in electricity, presented mainly from the experimental point of view, but including one demonstration lecture each week. Prerequisite: course 3. Mj. Winter, 4 sections, 8:00–10:00, 10:00–12:00, 1:30–3:30, 3:30–5:30, Associate Professor Lemon, Mr. Tucker, Mr. Fischer, Mr. Knudsen; Spring, 3 sections, 8:00–10:00, 10:00–12:00, 1:30–3:30, Associate Professor Lemon, Mr. States, Mr. Taylor, Mr. Blankenstein.

5. Heat, Sound, and Light.—A general college course in heat, sound, and light, presented mainly from the experimental point of view, but including one demonstration lecture each week. Prerequisite: course 4. Mj. Autumn, 2 sections, 8:00–10:00, 10:00–12:00, Associate Professor Lemon, Mr. Taylor, Mr. Tucker; Spring, 4 sections, 8:00–10:00, 10:00–12:00, 1:30–3:30, 3:30–5:30, Associate Professor Lemon, Mr. Tucker, Mr. Harris, Mr. Knudsen.

3S. Mechanics, Molecular Physics, and Heat.—A general college course in mechanics, molecular physics, and heat presented from the experimental point of view, not containing demonstration lectures. Prerequisite: entrance Physics or course 2 and Trigonometry. Mj. Summer, 2 sections, 7:00–9:00, 1:30–3:30, Mr. Akeley and Mr. Hutchinson; Spring, 2 sections, 8:00–10:00, 10:00–12:00, Mr. Hutchinson and Mr. McAllister.

4S. Electricity, Sound, and Light.—A general college course in electricity, sound, and light presented from the experimental point of view, not containing demonstration lectures. Prerequisite: course 3S or courses 3 and 4. Mj. Summer, 2 sections, 10:00–12:00, 1:30–3:30, Mr. Knudsen and Mr. States; Autumn, 2 sections, 8:00–10:00, 12:30–2:30, Mr. Akeley, Mr. States.

II. SENIOR COLLEGE COURSES

7. Lecture Demonstration Course.—A course of demonstration lectures covering the entire field of Physics designed to supplement courses 3S and 4S. Especial attention is given to modern points of view; the kinetic theory of heat, the atomic theory of electricity, and the electrical theory of matter receiving especial attention. The attempt is made to repeat a majority of the classical demonstrations of Kelvin, Faraday, Thomson, and others. This course includes the demonstration lectures of courses 3, 4, and 5. It may be registered for during the Autumn, Winter, and Spring, University College. Students so registering or students taking this course in the summer receive Senior College or graduate credit. Prerequisite: courses 3S and 4S or their equivalent. Mj. Summer, 9:00, Mr. Taylor; ½Mj. per Quarter, Autumn, Winter, Spring, 7:00–9:00 P.M., Tu., Mr. Taylor.

9. Radio Telegraphy and Telephony, I.—A course of lectures and laboratory work consisting of elementary consideration of the fundamental laws and their applications to the circuits of modern radio telegraph and telephone systems. Experimental adjusting of radio circuits. Prerequisite: courses 3 and 4. Mj. Summer and Spring, 8:00–10:00, Mr. Kannenstine.

10. Elementary Mathematical Physics.—A lecture course on the application of elementary calculus to physics and chemistry, and practice in the solution of problems. Prerequisite: Physics 4S or 5, and Calculus. Mj. Autumn, 10:00, Professor Gale.

11. The Kinetic Theory.—A lecture course for advanced and graduate students, covering the kinetic theory, of gases, liquids, and solids. Prerequisite: Physics 4S or 5 and Calculus. Mj. Summer, 8:00, Dr. Loeb; Winter, 1:30, Associate Professor Lemon.

12. Light.—A lecture course for advanced students covering the more important sections of geometrical and physical optics. Prerequisite: Physics 4S or 5 and Calculus. Mj. Winter, 9:00, Professor Gale.

12A. Physical Optics.—An intermediate course in physical optics dealing especially with diffraction, dispersion, and polarization. M. Summer, First Term, 9:00, PROFESSOR GALE.

13. Electricity and Magnetism.—A course of advanced work in Theoretical Electricity and Magnetism, with many applications to electrical and magnetic apparatus and measurements. Prerequisite: Physics 4S or 5 and Calculus. Mj. Winter, 10:00, ASSISTANT PROFESSOR DEMPSTER.

14. The Teaching of Physics in High School.—Historical survey present-day standard courses. The purposes of teaching physics from the educational standpoint. Corresponding principles of classroom and laboratory instruction. Particular methods, "mastery," "project," etc. A critical comparison of textbooks. Demonstrations of typical presentations of physical principles. Prerequisite: Physics 1 and 2, or equivalent. Mj. Summer (or M. First Term), 2:30, MR. FISCHER.

16. Experimental Physics (Advanced): Molecular Physics and Heat.—A course of advanced laboratory work involving the determination of vapor pressures and densities, coefficients of friction of gases and liquids, molecular electrical conductivities, freezing- and boiling-points, latent and specific heats, high and low temperatures, radioactive constants, etc. Prerequisite: course 4S or 5. Mj. Autumn, 2:30–4:30, ASSOCIATE PROFESSOR LEMON.

17. Experimental Physics (Advanced): Light.—A course of advanced laboratory work in Light, consisting of accurate measurements in diffraction, dispersion, interference, and polarization. Prerequisite: course 4S or 5. Mj. Summer, 10:00–12:00, MR. TAYLOR; Autumn, 8:00–10:00; Winter, 8:00–10:00, MR. TAYLOR.

18. Experimental Physics (Advanced): Electricity and Magnetism I.—Laboratory work of the same grade as courses 16 and 17, but consisting of measurements in Electricity and Magnetism. Prerequisite: Physics 4S or 5. Mj. Summer, 2:30–4:30, MR. KANNENSTINE; Spring, 2:30–4:30, ———.

19. Experimental Physics (Advanced): Electricity and Magnetism II.—Laboratory work accompanied by lectures consisting of the theory and operation of dynamos, motors, transformers, wireless-telegraph apparatus. Prerequisite: Physics 4S or 5. Mj. MR. KANNENSTINE. [Not given in 1922–23.]

20. Physical Manipulation.—A series of exercises not provided in the regular courses of Experimental Physics, but important to the teacher or advanced student. It consists of the following groups:

Group A. *Shopwork* includes the cutting, filing, drilling, tapping, soldering, and polishing of metal, screw-cutting, and elementary lathework.

Group B. *Glasswork* includes the cutting, grinding, drilling, polishing, and testing of glass.

Group C. *Glass-blowing* includes the simpler processes in glass-blowing, such as cutting, bending, and joining of tubes, blowing bulbs, sealing in electrodes, etc.

Group D. *Chemical Processes and Physical Preparations* include the silvering of glass, cleaning and distillation of mercury, preparation of fibers for suspension, and materials useful in experimental work.

Group C only. M. First Term. Repeated Second Term. Registration permitted only on consultation with instructor. Summer, 1:30–3:30, MR. MONK.

21. Radioactivity and Discharge through Gases.—A laboratory course for Senior College and Graduate students. Mj. Winter, 2:30–4:30, ASSISTANT PROFESSOR DEMPSTER.

22. Electrical Circuits.—A course of lectures accompanied by occasional demonstrations on electric circuit phenomena, including magnetic fields, electromagnetic induction, oscillatory circuits, vacuum tube circuits, induction in iron, lternating currents, electric filters, transmission in lines. Prerequisite: Physics

3, 4, 5 and Calculus. Mj. Assistant Professor Dempster. [Not given in 1922–23.]

28. Photographic Processes.—Lectures and laboratory work on the laws of photographic action. Effects of exposure and development on opacity and density; orthochromatism, plate grain, speed, intensification, reduction, and the applications of these to the photography of exceptional subjects. Prerequisite: Calculus. Mj. Spring, 1:30–3:30, Associate Professor Lemon.

III. GRADUATE COURSES

31, 32, 33. Theoretical Physics.—A series of lectures chiefly in Theoretical Physics, Hydrodynamics, Elasticity, Capillarity, Molecular Physics, Thermodynamics, Wave-Motion Sound, Optical Theories, Electricity and Magnetism. 4 hours a week. Prerequisite: Physics 10, 11, and 13 and Calculus. Mj. Autumn, Winter, and Spring, 11:00, Professor Michelson.

37, 38, 39. Experimental Physics.—A course of laboratory work, chiefly devoted to the repetition of classical experiments, such as Determination of the Mechanical Equivalent of Heat; Maxwell's "V"; Hertzian Oscillations; Relative and Absolute Wave-Lengths, etc. 10 hours a week. Prerequisite: Physics 16, 17, 18. 3Mjs. Autumn, Winter, Spring, Professors Michelson, Gale, Associate Professor Lemon, and Assistant Professor Dempster.

40, 41, 42, 43. Research Course.—This course is intended for graduate students who are prepared to undertake special research. Except in the case of a purely mathematical problem, the entire time is to be devoted to work in the laboratory. DMj. Summer, Autumn, Winter, and Spring, Professors Michelson, Gale, Associate Professor Lemon, and Assistant Professor Dempster.

45. Aëronautics.—A course of lectures accompanied by a few demonstration experiments on the mechanical principles of flight. Dynamic similitude, elementary aërodynamics of fluid resistance, and the classical theory of Rayleigh form the principal theoretical topics. Much time is given to the discussion of the experimental work of Eiffel and the National Physical Laboratory on flat and cambered aërofoils, lift and drift coefficients. The Phugoid theory of Lanchester, longitudinal lateral and directional stability are taken up, as well as the modern gyroscopic devices of control. Prerequisite: Calculus and Elementary Mechanics, or consent of instructor. Mj. Associate Professor Lemon. [Not given in 1922–23.]

48. Spectrometry I.—Laboratory work in photographing and measuring the spectra of various elements. Use of the concave grating, echelon, and interferometer. Prerequisite: consent of the instructor. Mj. Winter, 2:30, Professor Gale.

52. Electron Theory I.—A course of graduate lectures covering the work of the last twenty years on the electrical properties of gases, the electron theory, and radioactivity. Prerequisite: two years of college Physics and Calculus. Mj. Autumn, 1:30, Assistant Professor Dempster.

53. Electron Theory II.—A continuation of 52, dealing with the application of the electron theory to metallic conduction, to the Seebeck, Peltier, Thomson, and Hall effects, to optical phenomena in magnetic fields, to the subject of electromagnetic mass, etc. Mj. [Not given in 1922–23.]

56. Quantum Theories and Theories of Atomic Structure.—A course of graduate lectures dealing with X-rays and the related phenomena, the study of which has thrown new light upon the structure of the atom and the relations of the atom and the molecule. Prerequisite: college Physics and Calculus. Mj. [Not given in 1922–23.]

59. Modern Spectroscopic Theories.—Application of the Bohr-Sommerfeld theories to X-ray spectra, series, fine structure, Stark effect, etc. Prerequisite: two years of college Physics and Calculus. Mj. Spring, 9:00, Professor Gale

110. Relativity and Electron Theory.—A brief survey of the elements of vector analysis, using Gibb's notation. Restricted principle of relativity; foundations of electrodynamics: electrodynamics of the electron; radiation. Electromagnetic fields in material media; electromagnetic theory of light; electron theory of dispersion; general relativity and Einstein's theory of gravitation. Mj. Summer (or M. either Term), 9:00, PROFESSOR PAGE.

120. Thermodynamics, Radiation, and Quantum Theory.—The fundamentals of thermodynamics; typical applications; entropy and probability; thermodynamics and radiation; Kirchhoff's Law, Stefan's Law; Wien's Law; the classical electrodynamics and equipartition of energy; Rayleigh-Jeans' Law; Theories of Planck, Larmor, Poincaré, etc. The quantum theory; application to specific heats, photoelectric effects, etc.; the Bohr-Sommerfeld theory of atomic structure. Prerequisite: College Physics and Calculus. Mj. Summer, (or M. either Term), 8:00, PROFESSOR SWANN.

130. The Electrical Properties of Gases.—Historical introduction; ionization by collisions in gases; theory of positive column; Hall effect in gases; theory of cathode fall of potential; electrical properties of flames; velocity of ions in flames; emission of electrons by hot bodies. Mj. Summer (or M. either Term), 10:00, PROFESSOR WILSON.

275. Physics Club.—This organization, consisting of all instructors and graduate and advanced students in the Department, meets on Thursday of each week from 4:30 to 6:00 for the discussion of recent research.

Attention is called to the following courses in the Departments of Mathematics and Astronomy. Descriptions of these and additional courses may be found in this *Circular* under the announcements of the respective departments:

Mathematics 27. Units and Dimensions.—Mj. Autumn, 1:30, ASSOCIATE PROFESSOR LUNN.

Mathematics 160. Vector Analysis.—Mj. Summer, 10:00, ASSOCIATE PROFESSOR LUNN.

Mathematics 165. Thermodynamics.—Mj. Winter, 9:00, ASSOCIATE PROFESSOR LUNN.

Mathematics 166. Dynamics of Continuous Media.—Mj. Autumn, 2:30, ASSOCIATE PROFESSOR LUNN.

Mathematics 168. Canonical Equations and Quantum Theory.—Mj. Winter, 8:00, ASSOCIATE PROFESSOR LUNN.

Mathematics 170. Statistics and Probability.—Mj. Summer, 11:00, ASSOCIATE PROFESSOR LUNN.

Astronomy 5. Analytic Mechanics (Statics).—Mj. Autumn, 9:00, PROFESSOR GALE.

Astronomy 6. Analytic Mechanics (Dynamics).—Mj. Winter, 9:00, ASSOCIATE PROFESSOR MACMILLAN.

Astronomy 21. Advanced Mechanics.—Mj. Autumn, 9:00, ASSOCIATE PROFESSOR MACMILLAN.

Astronomy 22. Introduction to Celestial Mechanics I.—Mj. Summer, 1:30, PROFESSOR MOULTON; Spring, 9:00, ASSOCIATE PROFESSOR MACMILLAN.

Astronomy 23. Introduction to Celestial Mechanics II.—Mj. [Not given in 1922–23.]

TABULAR VIEW OF COURSES OFFERED BY THE DEPARTMENT OF PHYSICS, 1922–23

Junior College courses are in italics; Senior College courses in capitals; Graduate courses in Roman type

Hour	Summer, 1922	Autumn, 1922	Winter, 1923	Spring, 1923
7:00	3S*a*. *Mechanics, Molecular Physics and Heat* 7:00–9:00 (Akeley)			
8:00	9. RADIO TELEGRAPHY AND TELEPHONY 8:00–10:00 (Kannenstine) 11. KINETIC THEORY (Loeb) 120. Thermodynamics: Radiation and Quantum Theory (Mj. or M. either T.) (Swann)	1*a*. *Elementary Physics* 8:00–10:00 (Hutchinson) 3*a*. *Mechanics* 8:00–10:00 (Knudsen) 4S*a*. *Electricity, Sound and Light* 8:00–10:00 (Akeley) 5*a*. *Heat, Sound, and Light* 8:00–10:00 (Tucker) 17. EXPERIMENTAL PHYSICS 8:00–10:00 (Taylor)	2*a*. *Elementary Physics* 8:00–10:00 (Hutchinson) 3*a*. *Mechanics* 8:00–10:00 (States) 4*a*. *Electricity* 8:00–10:00 (Knudsen) 17. EXPERIMENTAL PHYSICS 8:00–10:00 (Taylor)	4*a*. *Electricity* 8:00–10:00 (States) 5*a*. *Heat, Sound, and Light* 8:00–10:00 (Knudsen) 3S*a*. *Mechanics, Molecular Physics and Heat* 8:00–10:00 (Hutchinson) 9. RADIO TELEGRAPHY AND TELEPHONY 8:00–10:00 (Kannenstine)
9:00	7. LECTURE DEMONSTRATION COURSE (Mj. or M. either T.) (Taylor) 12A. PHYSICAL OPTICS ((M. 1st T.) (Gale) 110. Relativity and Electron Theory (Mj. or M. either T.) (Page)		12. LIGHT (Gale)	59. Modern Spectroscopic Theories (Gale)
10:00	130. Electrical Properties of Gases (Mj or M. either T.) (Wilson) 4S*a*. *Electricity, Sound and Light* 10:00–12:00 (Knudsen) Math. 160. Vector Analysis (Mj. or M. First T.) (Lunn) 17. Experimental Physics (Mj. or M. either T.) 10:00–12:00 (Taylor)	1*b*. *Elementary Physics* 10:00–12:00 (McAllister) 3*b*. *Mechanics* 10:00–12:00 (Knudsen) 5*b*. *Heat, Sound, and Light* 10:00–12:00 (Taylor) 10. ELEMENTARY MATHEMATICAL PHYSICS (Gale)	2*b*. *Elementary Physics* 10:00–12:00 (McAllister) 3*b*. *Mechanics* 10:00–12:00 (Taylor) 4*b*. *Electricity* 10:00–12:00 (Knudsen) 13. ELECTRICITY AND MAGNETISM (Dempster)	4*b*. *Electricity* 10:00–12:00 (Taylor) 5*b*. *Heat, Sound, and Light* 10:00–12:00 (Knudsen) 3S*b*. *Mechanics, Molecular Physics and Heat* 10:00–12:00 (McAllister)

TABULAR VIEW OF COURSES OFFERED BY THE DEPARTMENT OF PHYSICS, 1922–23—*Continued*

Hour	Summer, 1922	Autumn, 1922	Winter, 1923	Spring, 1923
11:00	Math. 170. Statistics and Probability (Mj. or M. 1st T.) (Lunn)	31. Theoretical Physics (Michelson)	32. Theoretical Physics (Michelson)	33. Theoretical Physics (Michelson)
12:30		4S*b*. *Electricity, Sound, and Light* 12:30–2:30 (States)		
1:30	1. *Elementary Physics* (DM. 1st T.) 1:30–4:30 (McAllister) 2. *Elementary Physics* (D.M. 2d T.) 1:30–4:30 (Blankenstein) 3S*b*. *Mechanics, Molecular Physics and Heat* (Mj. or M. either T.) 1:30–3:30 (Hutchinson) 4S*b*. *Electricity, Sound and Light* 1:30–3:30 (States) Astron. 22. Celestial Mechanics (Mj. or M. 1st T.) (Moulton) 20C. Physical Manipulations 1:30–3:30 (Monk)	1*c*. *Elementary Physics* 1:30–3:30 (Harris) 3*c*. *Mechanics* 1:30–3:30 (Fischer) 52. Electron Theory I (Dempster)	2*c*. *Elementary Physics* 1:30–3:30 (Harris) 3*c*. *Mechanics* 1:30–3:30 (Akeley) 4*c*. *Electricity* 1:30–3:30 (Fischer) 11. Kinetic Theory (Lemon)	4*c*. *Electricity* 1:30–3:30 (Blankenstein) 5*c*. *Heat, Sound, and Light* 1:30–3:30 (Harris) 28. Photographic Processes 1:30–3:30 (Lemon)
2:30	14. Teaching of Physics in High Schools (Mj. or M. 1st T.) (Fischer) 18. Experimental Physics 2:30–4:30 (Kannenstine)	16. Experimental Physics 2:30–4:30 (Lemon)	21. Radioactivity and Discharge Through Gases 2:30–4:30 (Dempster) 48. Spectrometry (Gale)	18. Experimental Physics 2:30–4:30 (———)

TABULAR VIEW OF COURSES OFFERED BY THE DEPARTMENT OF PHYSICS, 1922–23—*Continued*

Hour	Summer, 1922	Autumn, 1922	Winter, 1923	Spring, 1923
3:30		3*d*. *Mechanics* 3:30–5:30 (Blankenstein)	3*d*. *Mechanics* 3:30–5:30 (Blankenstein) 4*d*. *Electricity* 3:30–5:30 (Tucker)	5*d*. *Heat, Sound, and Light* 3:30–5:30 (Tucker)
4:30	275. Physics Club Th. 4:30–6:00	275. Physics Club Th. 4:30–6:00	275. Physics Club Th. 4:30–6:00	275. Physics Club Th. 4:30–6:00
7:00–9:00				
Hours to be Arranged	38. Experimental Physics (M. or DM. either T.) (Gale) 40. Research Course (M. or DM. either T.) (Gale)	37. Experimental Physics (Michelson, Gale, Lemon and Dempster) 41. Research Course (Michelson, Gale, Lemon and Dempster)	38. Experimental Physics (Michelson, Gale, Lemon and Dempster) 42. Research Course (Michelson, Gale, Lemon and Dempster)	39. Experimental Physics (Michelson, Gale and Lemon) 43. Research Course (Michelson, Gale and Lemon)

THE DEPARTMENT OF CHEMISTRY

OFFICERS OF INSTRUCTION

JULIUS STIEGLITZ, PH.D., SC.D., CHEM.D., Professor and Chairman of the Department of Chemistry.

WILLIAM DRAPER HARKINS, PH.D., Professor of Chemistry.

HERMANN IRVING SCHLESINGER, PH.D., Associate Professor of Chemistry.

ETHEL MARY TERRY, PH.D., Assistant Professor of Chemistry.

JOHN WILLIAM EDWARD GLATTFELD, PH.D., Assistant Professor of Chemistry.

BEN H. NICOLET, PH.D., Assistant Professor of Organic Chemistry.

MARY MEDA RISING, PH.D., Instructor in Chemistry.

HOWARD ADLER, PH.D., Instructor in Chemistry.

WILLIAM ALBERT NOYES, JR., SC.D., Instructor in Chemistry.

ADELINE DE SALE LINK, PH.D., Instructor in Chemistry.

JOHN F. MCBRIDE, S.B., S.M., Research Instructor in Organic Chemistry.

LILLIAN EICHELBERGER, PH.D., Research Instructor in Organic Chemistry.

MORRIS KHARASCH, PH.D., National Research Fellow in Organic Chemistry.

GEORGE LINDENBERG CLARK, PH.D., National Research Fellow in Physical Chemistry.

MARTIN CHARLES EDWARD HANKE, PH.D., National Research Fellow in Organic Chemistry.

ROBERT SANDERSON MULLIKEN, PH.D., National Research Fellow in Physical Chemistry.

ROGER WILLIAM RYAN, S.B., Assistant Curator.

WILLIAM ALMON MANN, S.B., S.M., Research Associate in Physical Chemistry.

VERNE DONALDSON SNYDER, S.B., Lecture Assistant.

MARIE FARNSWORTH, S.B., Assistant in Quantitative Analysis.

BENJAMIN R. HARRIS, Assistant in Physical Chemistry (Summer).

WALTER MCCONNELL HINMAN, S.B., Assistant in Qualitative Analysis.

ANDREW MCNALLY NEFF, S.B., Assistant in Organic Chemistry.

HAYWOOD MORRISON SEVERANCE, S.B., S.M., Assistant in General Chemistry.

HENRY KELLY BUCKNER, A.B., S.M., Assistant in Physical Chemistry.

ARTHUR COHEN, S.B., Assistant in Chemistry.

EARL C. GILBERT, S.B., S.M., Assistant in Chemistry.

HARRY VICTOR HUME, S.B., Assistant in Quantitative Analysis.

KARL STONE MEANS, S.B., Assistant in Chemistry.

ARCHIBALD T. MCPHERSON, A.B., A.M., Assistant in Organic Chemistry.

ESME EUGENE ROSAIRE, S.B., S.M., Assistant in General Chemistry.

REUBEN BENJAMIN SANDIN, A.B., A.M., Assistant in Chemistry.

MARK WATKINS TAPLEY, S.B., Assistant in Chemistry.

MARGARET FITCH WILLCOX, A.B., Assistant in Chemistry.

EDWARD CURTIS FRANKLIN, PH.D., Professor of Chemistry, Stanford University (Summer, 1922).

RAYMOND D. MULLINIX, PH.D., Professor of Chemistry, Rockford College (Summer, 1922).

GERHARD DIETRICHSON, PH.D., Assistant Professor of Physical Chemistry, University of Illinois (Summer, 1922).

FELLOWS, 1921–22

Samuel King Allison, S.B.
Benjamin R. Harris, S.B., S.M.
Herman Bernhard Siems, S.B. (Swift Fellow)
James Kidder Stewart, S.B. (Loewenthal Fellow)
Margaret Fitch Willcox, A.B. (Edith Barnard Fellow)
Robert Stern Landauer, Ph.D. (DuPont Fellow)
Julian Francis Smith, S.M.
Maude Frances Martin, A.B.

INSTRUCTIONAL WORK

The Department aims to prepare students (1) for government service, (2) to teach in colleges or universities, (3) to teach in secondary schools, (4) to fill positions as technical experts or assistants in chemical industries, (5) to become analysts in commercial and sanitary laboratories. The elementary courses may be taken with advantage by students having none of these ends in view.

Special stress will be placed on thoroughness of preparation and the symmetrical development of the student's knowledge. The object of the courses will be not so much to train specialists as to prepare the student to undertake intelligently all kinds of work of a chemical nature. Those intending to become practical chemists will find a thorough course of purely scientific chemistry the best basis for future specialization in any branch of the subject. Those who incline toward inorganic chemistry will be required to do much physical and a considerable amount of organic work; those proposing to become organic chemists will be required to do work in inorganic chemistry and physical chemistry of a more advanced nature than that given in the elementary courses. The test of time and the experiences of the graduates of the Department have fully justified this form of training.

RESEARCH

Students are encouraged to begin research work as soon as their preparation justifies it. Facilities for research in all lines, whether of inorganic, organic, analytical, radioactive, or physical chemistry, are provided. Special opportunities to pursue entirely independent research work, as guests of the University (see p. 5), will be given to maturer students who have already obtained the Doctor's degree. Besides a number of general University Fellowships which are usually allowed to the Department for candidates for the Ph.D. degree, there are four specially endowed Fellowships in Chemistry with a return of from $120 to $920 per year (three quarters): the Swift Fellowship, endowed by Mrs. Gustavus F. Swift; the DuPont Fellowship, granted by the E. I. du Pont de Nemours Company; the Loewenthal Fellowship, a memorial to Joseph B. Loewenthal; and the Edith Barnard Fellowship, a memorial to Edith Ethel Barnard, a former instructor, donated by her friends and family.

SCHOLARSHIPS IN CHEMISTRY

Besides the regular University Scholarships (p. 7) which are available for graduate and undergraduate students in chemistry, there is a special scholarship in Chemistry, The Joseph B. Triner Scholarship, donated by Joseph B. Triner to be awarded to a Czecho-Slovak student entering the University for work in Chemistry.

ARRANGEMENT OF COURSES

1, 2, 3, 2S, 3S, General Chemistry, Inorganic; 4 (or 4S) Elementary Organic; 6, 7, 10, 38, Qualitative Analysis; 8, 9, 11–19, Quantitative Analysis; 20 (or 20S) Elementary Physical Chemistry; 24, Elementary Colloid Chemistry; 25, Toxicology; 26, Detection of Poisons; 30–49, Advanced Organic Chemistry; 50–59, Advanced Inorganic Chemistry; 60–74, Advanced Physical Chemistry; 75–79, Radio-Chemistry; 90–101, Research.

REQUIREMENTS FOR DEGREES

THE DEGREE OF DOCTOR OF PHILOSOPHY

I. *Chemistry the primary subject.*—When the degree of Doctor of Philosophy in Chemistry is desired, the branch of chemistry touched by the dissertation is offered as a *major* subject and some other branch of chemistry as the *first minor* subject. Besides this, a sufficient knowledge of other fundamental phases of the science is required as well as sufficient work in a *second minor* subject in some other department. These conditions are complied with when the following specific requirements are fulfilled:

1. The presentation of a dissertation embodying the result of original research in General, Inorganic, Analytical, Organic, Physico-organic, or Physical Chemistry, or Radioactivity. This must constitute a real contribution to knowledge, and the work is usually done under the direction of an officer of the Department.

2. The general requirements for all candidates, in advance of General Chemistry: courses 4[1] (or 4S), 6–9, 11 (½Mj.), 20 (or 20S).

3. In addition to the above, one of the following specific sets of requirements, arranged according to the thesis subject:

General Chemistry and Inorganic Chemistry: courses 60, 61, 35 (or 30 and 31), 50, 51 and 52 or 63, and one major taken from courses 12–19, 30–38, 47, 48, 52, 63; *Organic Chemistry:* courses 30–32, 35[2]–37, 39, 50, 60 or 61 or 62. *Physico-organic Chemistry:* courses 30–32, 35, 36, 50, 60, 61, and one major taken from courses 10, 12–19, 38, 39, 47, 48, 51, 52, 62, and 63. *Physical Chemistry:* courses 60, 61, 62, 35 (or 30 and 31), 50, and 63, and one major taken from courses 10, 12–19, 30–32, 36–38, 47, 48, 51, 52, 63. *Radioactivity* or *Photo-Chemistry:* courses 60, 61, 62, 50, 75 and 76, and Physics 52 (Electron Theory), and one major taken from courses 10, 12–19, 30–32, 35–38, 52 and 63. In addition to one set of these specific requirements at least six half-majors will be chosen from the special courses 38, 40–49, 55–59, 64–79. As a final test of preparation for research work a student as a rule will be asked to repeat without assistance some piece of published work, generally as a half-major included in courses 37, 51 or 52, 63 or some similar course. The research work will require from four to six quarters.

4. Sufficient work of an advanced character in another department to make a *second minor* of *three majors*. The following are the requirements for such a minor in various departments: (*a*) In *Physics:* three of the courses 11, 12, 13, 16, 17, 18, 19, 48, 49, 51, 52, 53, 55 or 56; courses, 3 4, 5 are prerequisite to these.

[1] Course 4 may be omitted by graduate students when advanced work in Organic Chemistry is taken.

[2] Course 35 will be omitted when courses 30–31 have included laboratory work.

(*b*) In *Physiological Chemistry:* three majors selected from 19, 20, 24, 25, 37, 38, 39, or 42. (*c*) In *Geology:* courses 15, 16, and 52 or their equivalent. Courses 7 or 8, and 11, 12, 14 would be prerequisite to these courses. (*d*) In *Geography:* courses 17, 18, 21, and their prerequisite courses. (*e*) In *Hygiene and Bacteriology:* course 12 and two majors in course 15; courses 2 and 3 are prerequisite to these. With permission, course 10 or 11 may be substituted for course 12. (*f*) In *Home Economics* (Food Chemistry and Nutrition): 3 Majors selected from courses 36 to 42, or 50. (*g*) In *Physiological Chemistry* and *Food Chemistry:* any three courses listed under (*b*) and (*f*), but Physiological Chemistry 19 and Home Economics 36 must not *both* be offered, nor both Physiological Chemistry 20 and Home Economics 38A.

II. *Chemistry the secondary subject.*—When Chemistry is a secondary subject, the requirement is determined after conference with the Head of the Department in which the major work is done. Courses 6, 7, and 8, and five other majors in advance of 8, will be required when Chemistry is the only secondary subject; courses 6, 7, and 8, and two other majors, when Chemistry is one of two secondary subjects. Elementary Physical Chemistry or Organic Chemistry, according as the major subject belongs to the Physical or the Biological Group, is recommended. When Physics is the major subject and Chemistry the minor, five majors beyond course 8 will be required with emphasis on Quantitative Analysis and Organic Chemistry.

THE MASTER'S DEGREE

For the Master's degree in Chemistry a dissertation and eight majors of graduate work in Chemistry are required if all the work is in Chemistry. These majors must be selected from courses in advance of 9, with the approval of the Chairman of the Department. Courses prerequisite to these must be taken, but cannot be counted in reckoning the eight required majors. At least one course in Physical Chemistry and one in Organic Chemistry must be included in the courses taken if they have not been taken before.

Up to three chemistry courses given in the Departments of Physiological Chemistry, Geology, and Home Economics may be included in these eight majors.

The eighth major of graduate work will be devoted to specific preparation (in residence) for the dissertation, either in the laboratory (research) or in the library (historical work).

Courses leading to the doctorate and Master's degrees in the Chemistry of Nutrition are given in the Department of Home Economics in conjunction with other departments.

THE DEGREE OF BACHELOR OF SCIENCE

Chemistry may be taken as a major subject to fulfil the requirement for a principal sequence or as a minor subject to fulfil the requirement for a secondary sequence. Guidance as to a more thorough preparation in college for professional work in Chemistry is given below (p. 42).

I. PRINCIPAL SEQUENCES

1) Courses 2, 3 (or 2S, 3S), 4 (or 4S), 6, 7, 8, 20 (or 20S), and any other two courses in the Department except 1.

2) Combination with other science departments:[1] By dropping the neces-

[1] Recommendation for appointment to teach Chemistry in a secondary school requires at least courses 2, 3 (or 2S, 3S), 4 (or 4S), 6, 7, 8, and 20. (See page 44.)

sary majors from the latter portion of sequence 1) above, nine major sequences may be offered involving the following courses: (1) three majors in College Physics, i.e., 3, 4, 5 (3S, 4S), but not 1, 2, preceding or accompanying six Chemistry courses enumerated in 1) above; (2) one to three majors in Geology selected from Geology 2, 3, 11, 12, 40–45, 50, 52, 53, when these courses follow Chemistry courses 2, 3 (or 2S, 3S), and 6; (3) two majors of Physiological Chemistry, provided they are taken after courses 2, 3 (2S, 3S), 4 (or 4S), and 6 in Chemistry; (4) two majors in Chemistry of Foods and Dietetics, provided these courses follow 2, 3 (2S, 3S), 4 (or 4S), and 6 in Chemistry.

II. SECONDARY SEQUENCES

a) For students specializing in Physics: courses, 2, 3, 6, 7, 8, and either 4 (or 4S).

b) For students specializing in Biological Science: courses 2, 3, 4 (or 4S), 6, 8, and 20.

c) For students specializing in Geology: courses 2, 3, 6, 7, 8, 9. The Department strongly advises courses 10, 14, and, in particular, 20.

SPECIAL STUDENTS

Special or unclassified students, not candidates for a degree, will be received, but in every case they will be required to give evidence, satisfactory to the instructors, that their previous training has been sufficient to enable them to derive full profit from the courses they propose to take.

PREPARATION FOR PROFESSIONAL WORK

GRADUATE WORK

1. *Preparation for Teaching in University and College Positions:* (*a*) For recommendations for major appointments in the larger universities and colleges only students who have taken the degree of Doctor of Philosophy will be considered to have had an adequate preparation. For certain university positions marked ability in research evidenced in the work for the degree will be considered essential. An academic career of real promise demands as never before research ability and training, which should give a man the broader viewpoint for the past and the future of his science, as well as the enthusiasm for his subject as a living science, which are the earmarks of the inspiring teacher. (*b*) For recommendations for chairs in Chemistry in smaller colleges the preparation demanded for the Master's degree will for the present be considered sufficient.

2. *Preparation for Technical and Government Work:* Thorough scientific training in all branches of chemistry as required for the Doctor's degree forms the best preparation for a career as a chemical expert in any branch of chemical industry. With this preparation the principles and details of technical processes are quickly grasped, advances in industrial processes are intelligently followed, and newly discovered principles are readily applied. A broad preparation, including advanced work in physical chemistry and mathematics for the candidate specializing in organic or inorganic chemistry, and vice versa, is strongly recommended.

All the more important requests received from technical establishments specify a doctorate of philosophy, with its training to do research work as a fundamental requirement.

For the more important government positions in Chemistry the doctorate of philosophy is generally demanded as an essential condition for candidacy.

UNDERGRADUATE WORK

I. For the college student who wishes to use his work for the Bachelor's degree as an opportunity toward preparation for professional work in Chemistry, a careful and logical selection of his courses during the four years of his college work is invaluable in the interest of a broad and adequate preparation with a minimum of wasted effort. For the benefit of such a student the following outline of essential courses is given with an indication of the sequence in which these are best taken. Students taking this course will be given the preference, other qualifications being equal, in recommendations for appointments for which they are fitted (see II below).

A. *General Outline of College Work*

(1) *English*, 2 majors, required of all college students in their first year. (2) *Chemistry*, 15 to 18 majors, to be described below. The student should start in his first year (Autumn or Summer) with Chemistry 1 or, if he has had high-school Chemistry, with 2S. (Entrance Physics is a prerequisite, and Physics 1 and 2 should be taken in the student's first two quarters if he has not had high-school Physics.) (3) *Physics*, 2 or 3 majors. Physics 3, 4, and 5 or 3S and 4S for students who have had Trigonometry. This work should be taken in the student's first or second college year. (Entrance Physics is a prerequisite, and Physics 1 and 2 should be taken in the student's first two quarters if he has not had high-school Physics.) (4) *Mathematics*, 3 majors (at least). Courses 1, 2, 3, and 15 in Mathematics, covering college algebra, trigonometry, analytical geometry and elementary calculus, are recommended for the student's first or second year. Advanced work in Calculus is desirable. (5) *Biology*, 1 or 2 majors. Zoölogy 1 and 5 or Botany 1 for students who have not had high-school work in Biology. (6) *German*, 3 majors (or two years of high-school German). A knowledge of scientific German is greatly to be desired for advanced work in Chemistry. The student is advised to take the German in his *second* (not in his first year) or third college year, preferably as extra work. *French* may be well taken in the same way. (7) *Elective:* 7 to 11 majors, or more, if high-school work included Trigonometry, German, Physics, Biology, and Chemistry.

B. *Sequence of Fundamental Courses in Chemistry*

(1) *General Inorganic Chemistry*, first year: 2S and 3S for students who have had high-school Chemistry, or 1, 2, and 3 for students who have not had admission Chemistry. On recommendation of the instructor, the laboratory work of course 3 or 3S may be omitted in the case of very able students and courses 4 or 6 (major) taken simultaneously with the lectures (½Major) of courses 3 or 3S. (2) *Qualitative Analysis*, 2 majors, Courses 6 and 7. (3) *Quantitative Analysis*, 3 majors. Courses 8, 9, and a major from courses 11–19. (4) *Organic Chemistry*, 3 to 3½ majors. Course 4 (or 4S) and courses 30 (½ major, lectures, Autumn), 31, and 32, or courses 4S, 33, and 32. (5) *Physical Chemistry* (third and fourth years), 2 to 3 majors, beginning with course 20. (6) *Elective*, 5 to 6 majors, to be taken in advanced courses in analytical chemistry (10–19) organic chemistry (35–38 and special lectures), inorganic chemistry (50–52 and special lectures), physical chemistry (60–63, and special courses), radioactivity, courses 75–79, physiological

chemistry (physiological chemistry 19, 20), chemistry of nutrition 1, or bacteriology (1, 2, 3), with a view to specialization in one of these branches. Students are advised to consult very freely and early in their course with a Departmental Adviser, whose name may be secured at the Dean's office or at the office of Kent Chemical Laboratory, Room 19.

II. 1. *Preparation for Teaching:* For recommendations for minor appointments in universities and colleges the work represented by the principal sequence of 9 majors in Chemistry required for the Bachelor's degree (see p. 41), supplemented by from three to eight majors of advanced work in Chemistry, as outlined above, will be considered an adequate preparation.

The work represented by the specified courses in the principal sequence of 9 majors in Chemistry (see p. 44), required for the Bachelor's degree, is at present considered preparation for teaching in secondary schools. These include Chemistry courses 2, 3 (or 2S, 3S), 4 (or 4S), 6, 7, 8 and 20. Men will find it advisable to be prepared also to teach Physics, Mathematics, or Geology. Women will find it wiser to combine Chemistry with Home Economics, Physics, Physiography, Physiology, Botany, or Zoölogy.

Four majors of work in Education are required for the teaching of High School Chemistry in the North Central Association. The following courses are recommended: Education 1 or 2 (Introduction to Education); Education 4 (Methods of Teaching in High Schools); Education 8 (Class Organization, Management, and Testing in High Schools); and one from the following list: Education 6 (Psychology of High-School Subjects); Education 10 (History of Modern Education); Education 36 (The Administration and Supervision of High Schools); ed Natural Science 10 (The Teaching of General Science); or ed Natural Science 52 (The Teaching of High-School Chemistry).

2. *Preparation for Technological Work:* Students who have taken from ten to eighteen majors of work in the Department, as outlined above, are able to fill satisfactorily positions as assistants in technical and analytical laboratories and, after some practical experience, to advance to positions of independent responsibility. The complete training represented by the work for the Ph.D. degree is recommended, however, as the only wholly adequate preparation for all desiring to make a profession of chemistry.

3. *Preparation for Government Work:* For minor positions (e.g., junior chemist in the United States service) the Bachelor's degree is considered sufficient. The principal sequence in Chemistry, required for the degree, should be supplemented by *advanced* work in two or three branches of Chemistry (Inorganic, Organic, Physical, Analytical). If possible, the full course outlined under A and B should be taken.

The Department does not pledge itself to secure positions for those who have carried out any one of the above-recommended sets of courses; but, as a matter of fact, competent students find suitable places quickly, and in the past the demand for chemists has far exceeded the supply, particularly in the case of the *more completely* trained graduates (Ph.D.'s).

CHEMICAL SOCIETIES

The Kent Chemical Society is a club of students open to all those who have

had six majors of Chemistry. The Society meets bi-weekly to listen to papers by members and others.

The Graduate Chemical Club is an informal club of men graduate students in chemistry, meeting for social and scientific purposes.

The Kappa Mu Sigma is a graduate Sorority of faculty women and women working for graduate degrees in some field of Chemistry. Advanced undergraduate women of high standing are eligible to associate membership.

The Chicago Section of the American Chemical Society holds monthly meetings (except in summer) which the students of the University are welcome to attend. Membership in the Society is open to advanced students at special rates.

LABORATORY FEE

There is a laboratory fee of $6.00 per major for all courses involving laboratory work in the Department of Chemistry. A deposit of $5.00 for breakage is also required of each student and must be renewed each successive quarter of work.

COURSES OF INSTRUCTION

NOTE.—After course 9, the courses are arranged in groups according to subjects: courses 11–19 include courses in Analytical Chemistry, 20 in Physical Chemistry, 21–29 in special subjects of a Senior College character, 30–49 in Organic Chemistry, 50–59 in Inorganic Chemistry, 60–79 in Physical Chemistry and Radioactivity; 80–89 are general in nature, and 90–101 are research courses. Nos. 30–36, 40–49, 50, 51, 55–59, 60–62, and 75–79 are open to, and suitable for, Senior College students.

NOTE.—*Undergraduate students, other than medical students, desiring to take any of the half-major courses offered by the Department are required to take in any given quarter two such half-major courses (equivalent to a major course).*

I. PRIMARILY FOR THE JUNIOR COLLEGES

1. Elementary General Chemistry: Inorganic I.[1]—Prerequisite: preparatory Physics. DM. Summer, First Term. Classroom, 6 hours a week; laboratory, 12 hours a week, PROFESSOR MULLINIX. Mj. Autumn. Classroom, 3 hours a week; laboratory, 6 hours a week, ASSISTANT PROFESSOR TERRY.

2. General Chemistry: Inorganic II (continuation of course 1)[2].—Prerequisite: course 1. DM. Summer, Second Term, PROFESSOR MULLINIX. Mj. Winter, ASSISTANT PROFESSOR TERRY.

NOTE.—Course 2, Winter Quarter, is a continuation of course 1, but may be entered by those having credit for admission Chemistry.

3. General Chemistry: Inorganic III (continuation of course 2).[2,3]—Prerequisite: course 2. Mj. Spring, ———.

NOTE.—Courses 1, 2, and 3 are consecutive courses. Separate credit is given for each, but students are advised not to take one course only. The aim of these courses is to give a definite idea of the fundamental principles of chemistry, and not to overburden the student with a mass of unconnected facts. The lectures will be experimental to a considerable extent. The courses are designed to meet the wants, not only of those who wish to go more deeply into chemistry, but of all who wish to study the science as part of a liberal education.

1N. Elements of Chemistry.—Primarily for student nurses. Classroom work, 3 hours a week; laboratory work, 4 hours a week. M. First Term, Spring, 1922, ASSOCIATE PROFESSOR SCHLESINGER.

[1] Limited-credit course: After a student has credit for 18 majors but less than 27, these courses will be credited at one-half major each; after he has credit for 27 majors they will not be credited at all.

[2] The classroom parts of courses 1, 2, 3, 2S, 3S, 4, 4S, or 6, may be taken without payment of laboratory fees by graduate students who have had equivalent courses in Chemistry.

[3] Students who receive a sufficiently high grade in the classroom and laboratory work of course 2 or 2S may be excused from the laboratory work of course 3 or 3S. Such students take the lectures of 3 or 3S as a half major and are permitted to take course 4 or 6 simultaneously with the lectures of course 3 or 3S if they so desire.

2S. General Inorganic Chemistry.[1]—For students who have had preparatory Chemistry. Prerequisite: preparatory Chemistry and preparatory Physics, one unit each. DM. Summer, First Term. Classroom, 6 hours a week; laboratory, 12 hours a week, Dr. Adler; Mj. Autumn. Classroom, 3 hours a week; laboratory, 6 hours a week, Associate Professor Schlesinger and ———.

3S. General Chemistry: Inorganic (continuation of course 2S)[1].—DM. Summer, Second Term, Dr. Adler; Mj. Winter, Associate Professor Schlesinger and ———.

Note.—Whenever, in exceptional cases, the preparation of a student in 2 or 2S justifies it, Qualitative Analysis may be substituted for 3 or 3S.

4. Elementary Organic Chemistry.[1]—Prerequisite: course 3 or 3S. Classroom, 3 hours a week; laboratory, 6 hours a week. Class-limit: 100 per quarter. Mj. Autumn, Assistant Professor Glattfeld; Winter, Dr. Rising; Spring, Assistant Professor Glattfeld.

4S. General Organic Chemistry.[1]—Prerequisite: course 3 or 3S. Classroom, 5 hours a week; laboratory, 12 hours a week; DM. First Term, Summer, Assistant Professor Glattfeld.

6. Qualitative Analysis (introductory course).[1]—The lectures deal with the chemistry of the analytical reactions, and special attention is given to the development and application of the laws of equilibrium and of solutions. This course is, in an important sense, one in advanced General Chemistry. Classroom, 2 hours a week; laboratory 8 hours a week. Prerequisite: course 3 or 3S. Mj. Summer, Professors Stieglitz and ———; Autumn and Spring, Dr. Rising; Winter, Dr. Adler.

7. Qualitative Analysis (continuation of course 6).—Mj. or DM. Summer, ———; Autumn and Spring, Dr. Rising; Winter, Dr. Adler.

Note.—Courses 6, 7, and 10 form a continuous course, which may be begun in any quarter. The aim of courses 6, 7, and 10 will be to train the student to do intelligent analytical work, based on a knowledge of the scientific principles of the subject, and to apply and amplify his knowledge of General and Physical Chemistry.

II. PRIMARILY FOR THE SENIOR COLLEGES

8. Quantitative Analysis (introductory course).—Chiefly laboratory work in gravimetric and volumetric analysis. Laboratory, 8 or 16 hours a week; lecture, 1 hour. Prerequisite: course 7. (May be taken simultaneously with course 6 or 7. Medical students will be admitted to the course after having taken course 6.) Mj. Summer, Autumn and Winter, Dr. Noyes; Spring, Dr. Adler.

8M. Quantitative Analysis.—A special course for premedical and medical students giving the elements of gravimetric and volumetric analysis. Prerequisite: course 6. M. Summer, Autumn, and Winter, Dr. Noyes; ½Mj. Spring, Dr. Adler.

9. Quantitative Analysis (continuation of course 8).—Laboratory, 10 or 20 hours a week. Mj. or DM. Summer, Autumn, and Winter, Dr. Noyes; Spring, Dr. Adler.

Note.—Courses 8 and 9 form a continuous course which may be begun in any quarter.

10. Advanced Qualitative Analysis (continuation of courses 6 and 7).—Prerequisite: courses 7 and 8. Mj. or DM. Laboratory, 10 or 20 hours a week. Summer, ———; Winter, Dr. Adler; Spring, Dr. Rising.

11. Theories and Methods of Quantitative Analysis.—½Mj. 2 lectures a week. Prerequisite: course 9. Winter, Dr. Noyes.

[1] The classroom parts of courses 1, 2, 3, 2S, 3S, 4, 4S, or 6, may be taken without payment of laboratory fees by graduate students who have had equivalent courses in Chemistry and of course 6 by undergraduate students who have had Qualitative Analysis.

12–19.—Special Methods in Quantitative Analysis.—

12. Standard Methods of Water Analysis	½Mj.
13. Standard Methods of Food Analysis	½Mj. or Mj.
14. Analysis of Iron, Steels, and Ferro-alloys	½Mj. or Mj.
16. Preparation and Analysis of Gases	½Mj.
17. Electrolytic Analysis, Gravimetric	½Mj.
18. Electrometric Titration	½Mj.
19. Advanced Rock and Mineral Analysis	Mj.

Laboratory work, 10 hours a week per major. Prerequisite: course 9, but for students in Domestic Science and for medical students, course 8. Summer, Autumn, Winter, Dr. Noyes; Spring, Dr. Adler.

20. Elementary Physical Chemistry.—An introductory survey course in elementary physical chemistry. Lectures, 3 hours; laboratory work, 6 hours. Prerequisite: course 8. Mj. Summer, First Term, Professor Harkins; Second Term, Dr. Dietrichson; Spring, Associate Professor Schlesinger.

24. Introduction to Colloid Chemistry.—An elementary treatment of the main features of colloid chemistry. Lectures, 2 hours a week; laboratory work, 7 hours a week. Prerequisite: Physics 4, Chemistry 8 and 20 or 20S. Mj. Summer, 1923, Assistant Professor Terry.

Note.—The lectures may be taken as one-half major without laboratory work.

25. Toxicology.—½Mj. Autumn, Professors Haines and Assistant.

26. Poisons and Their Detection.—A conference and laboratory course. M. Spring, Second Term, Professor Haines.

III. PRIMARILY FOR THE GRADUATE SCHOOL

30. Organic Chemistry.—Lectures, 3 hours a week; laboratory, 6 hours a week. Prerequisite: Quantitative Analysis 8, and for undergraduate students, Elementary Organic Chemistry (course 4, 4S or an equivalent). Mj. Autumn, Professor Stieglitz.

Note.—Undergraduates must have 18 majors of college credit before they are eligible for admission to course 30 or 31. Students who have had adequate laboratory work in Organic Chemistry are admitted to the lectures of courses 30, 31, 32, or 33, each one-half major, without payment of a laboratory fee.

31. Organic Chemistry (continuation of course 30).—Lectures, 3 hours a week; laboratory, 4 hours a week. Mj. Winter, Professor Stieglitz.

32. Organic Chemistry (continuation of course 31).—The aromatic series. Lectures, 2 hours a week; laboratory work, 6 hours a week. Prerequisite: course 31 (course 4 or 4S for medical and home economics students). Mj. Spring, Assistant Professor Nicolet.

33. Organic Chemistry (Advanced).—Fatty and aromatic series. Lectures, 5 hours a week; laboratory, 9 hours a week. Prerequisite: course 4 or 4S, DM. Second Term, Summer, Assistant Professor Glattfeld.

35. Organic Preparations.—Laboratory work, 10 or 20 hours a week. Prerequisite: courses 7 and 9, and Organic Chemistry. Mj. or DM. Summer, Associate Professor Glattfeld; Mj. Autumn, Winter, and Spring, Assistant Professor Nicolet.

36. Organic Preparations (continuation of course 35).—Prerequisite: course 35 or its equivalent and a reading knowledge of German or French. Mj. or DM. Summer, Assistant Professor Glattfeld; Mj. Autumn, Winter, and Spring, Assistant Professor Nicolet.

37. Organic Preparations (continuation of course 36).—Mj. or DM. Summer, Assistant Professor Glattfeld; Mj. Autumn, Winter, and Spring, Assistant Professor Nicolet.

Note.—Students who have taken the laboratory work of courses 30 and 31, or 31 and 32, or 31 and 33, will omit course 35 and go on with course 36.

38. Qualitative Organic Analysis.—Prerequisite: courses 32 or 33, and 35 and 36. Mj. Summer, DR. KHARASCH.

39. Organic Elementary Analysis.—Determinations of carbon, hydrogen, and nitrogen by combustion. Laboratory work, 60 hours. Required of all candidates for the PH.D. and S.M. (laboratory thesis) in Organic Chemistry. Summer, PROFESSOR STIEGLITZ; Autumn, ASSISTANT PROFESSOR NICOLET; Winter, DR. RISING; Spring, ASSISTANT PROFESSOR GLATTFELD.

40A. Principles of Organic Chemistry.—Lectures. Prerequisite: 3 majors of Organic Chemistry. ½Mj. Summer, 1921, DR. KHARASCH.

40B. Organic Synthesis.—Lectures. Prerequisite: 3 majors of Organic Chemistry. Mj. Spring, 1922, DR. KHARASCH.

40C. Organic Dyestuffs.—With special reference to the naphthalene, anthracene and carbazol series. Prerequisite: course 36. Lectures. ½Mj. Spring, DR. KHARASCH.

41. Stereochemistry.—Stereochemistry of carbon compounds and nitrogen compounds, including methods of determination of configuration; stereochemical interference. Prerequisite: 2 majors of Organic Chemistry. ½Mj. Winter, DR. RISING.

42. Carbohydrates.—½Mj. Spring, ASSISTANT PROFESSOR GLATTFELD.

43. Organic Nitrogen Derivatives.—Amino acids: polypeptids; uric-acid series; pyridine group; alkaloids; synthetic drugs. Prerequisite: course 31. ½Mj. PROFESSOR STIEGLITZ. [Not given in 1922–23.]

44. Physical Chemistry Applied to Organic Problems.—Lectures, 2 hours a week. Prerequisite: courses 31 and 20, 21, or 22. ½Mj. PROFESSOR STIEGLITZ, ASSISTANT PROFESSOR TERRY. [Not given in 1922–23.]

45. Selected Topics of Organic Chemistry.—Application of the electron theory to organic compounds; tautomerism; stereoisomerism; electromerism; organic dyestuffs. Prerequisite: Organic Chemistry. 4 lectures a week. M. Summer, First Term, PROFESSOR STIEGLITZ.

46. Special Topics of Organic Chemistry.—Prerequisite: Organic Chemistry. ½Mj. Autumn, ASSISTANT PROFESSOR NICOLET.

46A. Special Topics of Organic Chemistry in the Aromatic Series.—The electron structure of benzene, the rules of substitution, diazo-chemistry, condensed aromatic nuclei, aromatic derivatives of arsenic and mercury. Prerequisite: 2 majors of Organic Chemistry. 4 lectures a week. M. Summer, Second Term, DR. M. C. E. HANKE.

47. Catalysis.—Preparation and use of newer (solid) catalysts and promoters for organic reactions. Prerequisite: courses 11, 32 or 33, 35. Laboratory work, 10 hours a week. Mj. ASSISTANT PROFESSOR TERRY. [Not given in 1922–23.]

48. Electrolytic Processes of Organic Chemistry.—Lectures, 2 hours a week, laboratory, 7 hours a week. Prerequisite: courses 11, 32 or 33, 35. Mj. Autumn, ASSISTANT PROFESSOR TERRY.

NOTE.—The lectures in 47 or 48 may be taken as a half-major without laboratory work and without payment of a laboratory fee.

49. The Chemistry of Synthetic Drugs and Related Principles.—Structure and synthesis of typical alkaloids, synthetic drugs, and active principles of internal secretion. Prerequisite: 2 majors of Organic Chemistry. ½Mj. Winter, 1922, DR. RISING.

50. Inorganic Preparations.—Laboratory work, 10 or 20 hours a week; classroom work, 2 hours a week. Prerequisite: course 9. Mj., M. or DM. Summer, First Term, PROFESSOR HARKINS; Second Term, PROFESSOR FRANKLIN; Winter and Spring, ASSOCIATE PROFESSOR SCHLESINGER.

51. Inorganic Preparations (continuation of course 50).—Mj. or DM. Prerequisite: course 50 and a reading knowledge of German or French. Same schedule as course 50.

52. Inorganic Preparations (continuation of course 51).—Mj. or DM. Same schedule as course 50.

55A, B, C. Advanced Inorganic Chemistry.—A series of half-major lecture courses comprising a systematic course in advanced Inorganic Chemistry from the point of view of recent results and future problems. The groups of the periodic system will be studied critically, and such topics as temperature measurement, thermal analysis, transition points, alloys, will receive detailed treatment. Prerequisite: Elementary Organic Chemistry and Physical Chemistry 20. Course A, ½Mj. Winter; C, ½Mj. Spring, Associate Professor Schlesinger.

56. The Chemistry of Non-aqueous Systems.—Liquid ammonia as a typical non-aqueous solvent, and the ammono-system of chemical compounds (ammono-acids,-bases, and, -salts) including organic derivatives. 2 lectures per week. M. Summer, Second Term, Professor Franklin.

57A. The Structure of the Atom.—A non-mathematical course in the nucleus of the atom as related to atomic evolution, and on the arrangement of the planetary electrons as related to valence. Professor Harkins. [Not given in 1922–23.]

57B, C. Chemical Phenomena and Radioactivity.—From the point of view of atomic structure. Lectures. Each ½Mj. Professor Harkins. [Not given in 1922–23.]

58. The Constitution of Liquids and Solids: Surface Tension and Colloids.—Lectures. ½Mj. Professor Harkins. [Not given in 1922–23.]

60. Physical Chemistry.—Lectures, 3 hours; laboratory work, 6 hours. Prerequisite: Elementary Physical Chemistry 20 and the Elements of Calculus for undergraduate students; Quantitative Analysis and the Elements of Calculus for graduate students. Mj. Autumn, Professor Harkins.

61. Physical Chemistry: Electrochemistry (continuation of course 60).—Hours as in 60. Prerequisite: course 60 or its equivalent and Physics 3 and 4. Lectures. Mj. Winter, Professor Harkins.

62. Physical Chemistry: Applications of Thermodynamics and Kinetic Theory (continuation of course 61).—Lectures, 4 hours a week. Prerequisite: course 61 or its equivalent in Physics. Mj. Spring, Professor Harkins.

63. Physico-chemical Measurements.—Introductory to Research. Laboratory work, 10 or 20 hours a week. Prerequisite: course 61 and Physics 5. DM. Second Term, Summer, Dr. Dietrichson; Mj. Autumn, Winter, and Spring, Professor Harkins.

64. Crystal Structure and Valence as Related to Atomic Structure.—Lectures. ½Mj. Professor Harkins. [Not given in 1922–23.]

66. The Physical Mechanism of Chemical Processes and Chemical Applications of the Kinetic Theory.—Prerequisite: Physics 5, Calculus, Chemistry 20. ½Mj. Winter, 1922, Dr. Mulliken.

75. Subatomic Phenomena and Radioactivity.—Lectures from the point of view of the structure of atom nuclei. Prerequisite: course 20. ½Mj. Autumn, Professor Harkins.

76. Laboratory Course in Radioactivity.—To follow course 75. Limited to 6. ½Mj. Winter, Professor Harkins.

82. Club Meetings.—Meetings of the Kent Chemical Society will be held twice a month. They may be attended by anyone interested. The subjects for the meetings will be announced at least one week in advance. Summer, Autumn, Winter, and Spring.

85. The Chemistry and Preparation of Medicinal Drugs.—½Mj. Spring, Professor Haines.

90–96. Research Work (for the Ph.D. Degree).—These courses will include from 30 to 40 hours a week of laboratory work, under the special direction of some one of the instructors in the Department. It is expected that research work for a Doctor's dissertation will require 4–6 quarters (4–6 DMjs.). Before being admitted to research a candidate must satisfy the instructors of the Department that his previous training has been sufficient.

90. Research in Organic and Physico-Organic Chemistry.—Mj. or DMj. Summer, Autumn, and Winter, PROFESSOR STIEGLITZ.

91. Research in Physical Chemistry and Radioactivity.—Mj., DM., or DMj. First Term, Summer, Autumn, Winter, and Spring, PROFESSOR HARKINS.

92. Research in Inorganic and Physical Chemistry.—Mj. or DMj. Autumn, Winter, and Spring, ASSOCIATE PROFESSOR SCHLESINGER.

93. Research in Physico-Organic Chemistry.—Mj. or DMj. Autumn, Winter, and Spring, ASSISTANT PROFESSOR TERRY.

94. Research in Organic Chemistry.—Mj. Summer, Autumn, and Spring. ASSISTANT PROFESSOR GLATTFELD.

95. Research in Organic Chemistry.—Mj. or DMj. Autumn, Winter, and Spring, ASSISTANT PROFESSOR NICOLET.

98A. Master's Dissertation in Inorganic and Physical Chemistry.—Mj. Autumn, Winter, and Spring, ASSOCIATE PROFESSOR SCHLESINGER.

98B. Master's Dissertation in General Chemistry.—Mj. Autumn, Winter, and Spring, ASSISTANT PROFESSOR TERRY.

98C. Master's Dissertation in Organic Chemistry.—Mj. Summer, Autumn, and Spring, ASSISTANT PROFESSOR GLATTFELD.

98D. Master's Dissertation in Organic Chemistry.—Mj. Autumn, Winter, and Spring, ASSISTANT PROFESSOR NICOLET.

98E. Master's Dissertation in Qualitative Analysis or in Organic Chemistry.—Mj. Autumn, Winter, and Spring, DR. RISING.

98F. Master's Dissertation in Qualitative and Quantitative Analysis.—Mj. Summer, Winter, and Spring, DR. ADLER.

98G. Master's Dissertation in Quantitative Analysis.—Mj. Summer, Autumn, and Winter, DR. NOYES.

100. Independent Research.—Mj. Summer, Autumn, Winter, and Spring.

101. Research in the Chemistry of Food.—Mj. Summer, Autumn, and Spring, ASSOCIATE PROFESSOR BLUNT (Department of Home Economics).

CHEMISTRY COURSES IN THE DEPARTMENT OF PHYSIOLOGICAL CHEMISTRY

(See the Biological Group *Circular*)

CHEMISTRY COURSES IN THE DEPARTMENT OF GEOLOGY

50. Non-Metallic Mineral Deposits (except petroleum, natural gas, and asphalt).—A critical study of the nature, mode of occurrence, distribution, origin, treatment, and uses of the more important non-metallic deposits of economic importance, including coal. Several trips on Saturdays to mines, quarries, and plants in the vicinity. Prerequisite: Geology 2, 3, 5, a working knowledge of Chemistry, and 24 majors. Mj. Winter, 1:30, PROFESSOR BASTIN.

52. Genesis of Ore Deposits.—A study of the principles involved in the formation of ore deposits, and of the characteristic features of deposits formed under the wide variety of natural conditions. Individual mining districts will receive only incidental consideration as exemplifying the principles developed. Prerequisite: Geology 12, 16, and 40, and Chemistry 6. Laboratory fee, $6.00. Mj. Autumn, 9:00–11:00, PROFESSOR BASTIN.

53. Economic Geology of Metalliferous Deposits.—Deposits of the important metals will be studied seriatim with reference to the conditions under which

they were formed and the geologic factors influencing their exploitation. Reports will be required summarizing the economic geology of certain mining districts. Practice will be given in the use of mine maps and the compilation of geologic cross-sections through mines. Prerequisite: Geology 52. Mj. PROFESSOR BASTIN. [Not given in 1922–23.]

54. Field Work in Mining and Mining Geology.—Students in Mining Geology are advised to spend some of their summers in mining camps where they may find employment as miners, mine samplers, assayers, draughtsmen, surveyors, etc. For the sake of experience it is desirable that they serve in as many different capacities as practicable. In many mining camps opportunity is offered for a study of General Geology, ore deposits, mining machinery, metallurgical works, etc. Frequent communication with the instructor is required, and when the work and reports are sufficiently thorough, credit will be given. Prerequisite: courses 40 and 52. Summer, PROFESSOR BASTIN.

CHEMISTRY COURSES IN THE DEPARTMENT OF HOME ECONOMICS

35A. Elementary Organic and Food Chemistry (2).—A presentation of some of the most important parts of food chemistry, preceded by an elementary treatment of such portions of organic chemistry as are essential to an understanding of food composition. The work is chiefly organic chemistry and may be followed during the Second Term of the Summer Quarter by course 36. Laboratory and lecture. Prerequisite: General Chemistry. Laboratory fee, $3.00. M. Summer, First Term, lectures, M., W., 8:00, laboratory, Tu., Th., F., 8:00–10:00, ASSISTANT PROFESSOR HALLIDAY.

36. Chemistry of Food (3).—Chemistry of fats, carbohydrates, proteins, ash constituents, with special emphasis upon the composition and nutritive value of such foods as meat, flour, milk, butter, etc. Laboratory work, qualitative and quantitative. Prerequisite: Organic Chemistry. Laboratory fee, $6.00. Mj. Summer (or M. either Term), lectures, Tu., Th., 11:00, laboratory, M., W., F., 9:00–11:00, ASSISTANT PROFESSOR HALLIDAY; Mj. Autumn, Lectures, Tu., Th., 8:00, laboratory, M., W., F., 8:00–10:00, ASSOCIATE PROFESSOR BLUNT AND MISS BAUER; Spring, lectures, Tu., Th., 11:00, laboratory, M., W., F., 10:00–12:00, ASSISTANT PROFESSOR HALLIDAY.

37. Chemistry of Food (continued) **(3).**—A continuation of the more elementary course in food chemistry with greater emphasis on quantitative methods, including the use of the bomb calorimeter, the hydrogen ion concentration apparatus, and the Van Slyke amino nitrogen apparatus. Lecture and laboratory. Prerequisite: Home Economics 36 or its equivalent. Laboratory fee, $6.00. Mj. Winter, lectures, Tu., Th., 2:30, laboratory, M., W., F., 2:30–4:30, ASSISTANT PROFESSOR HALLIDAY.

38A. Nutrition (3).—Processes of digestion and metabolism and the nutritive requirements of the body, giving a scientific basis for the work in dietaries. Laboratory work: experiments on digestion and qualitative and quantitative urine analysis in connection with special diets. Students may follow this course by either 39 or 38B, or both. Prerequisites: Home Economics 36 and Physiology 0. Laboratory fee, $3.00. M. Summer, First Term, lectures, Tu., Th., 1:30, laboratory M., W., F., 1:30–3:30; M. Autumn, lectures, M., W., 2:30, laboratory, Tu., Th., F., 2:30–4:30; Spring, lectures, Tu., Th., 1:30, laboratory, M., W., F., 1:30–3:30, ASSOCIATE PROFESSOR BLUNT AND MISS BAUER.

38B. Nutrition (continued) **(3).**—The course may include blood analysis, some study of pathological conditions in metabolism and a feeding or metabolism experiment. Laboratory fee, $3.00. M. Summer, Second Term, lectures, Tu., Th., 1:30, laboratory, M. W., F., 1:30–3:30; M. Autumn, lectures, M., W., 2:30, laboratory, Tu., Th., F., 2:30–4:30; Spring, lectures, Tu., Th., 1:30, laboratory, M., W., F., 1:30–3:30, following 38A. ASSOCIATE PROFESSOR BLUNT AND MISS BAUER.

39. Dietaries (3).—Food requirements of individuals and families as modified by age, sex, activity, etc., with special consideration of the food of children. Theory of infant feeding. Prerequisite: Home Economics 2 or 3 and 38A. Laboratory fee, $6.00. Mj. Winter, 8:00–10:00, Assistant Professor Roberts.

40. Readings in Nutrition (4).—Recent literature on nutrition. Prerequisites: Home Economics 38A and 39A. Mj. Summer (or M. either Term), Tu., Th., 3:30–5:30; Mj. Spring, Tu., Th., 3:30–5:30, Associate Professor Blunt and Miss Bauer.

50. Research in Food and Nutrition (4).—Individual research along such lines as metabolism and diet of underweight, overweight, and normal women and children, animal-feeding experiments, food chemistry, chemical changes in cooking, etc. For properly trained graduate students, on permission of the instructor. May also be registered for as Chemistry 101. Where the subject investigated requires laboratory work the laboratory fee is $6.00. Mj. Summer (or DM. either Term), Autumn, Winter, Spring, hours to be arranged, Associate Professor Blunt and Other Members of the Department.

153A. Advanced Textiles (3).—Methods used in the physical and chemical examination of textiles and their commercial significance. Prerequisites: General Chemistry and 2 majors in Home Economics, including Home Economics 152, or at least 4 majors of Chemistry. Laboratory fee, $3.00. M. Summer, First Term, 10:00–12:00, Mrs. Supple.

TABULAR VIEW OF COURSES OFFERED BY THE DEPARTMENT OF CHEMISTRY, 1922–23

PART I.—Courses required for the principal sequence in chemistry and courses continued through the year. For laboratory courses and advanced lecture courses see Part II. Junior College courses are in italics; Senior College courses in Roman type.

Hour	Summer, 1922	Autumn, 1922	Winter, 1923	Spring, 1923
8:00	4S. *Elementary Organic Chemistry* DM. 1st Term 5 lectures weekly Lab.: M., Tu., W., Th. 1:30–4:30 (Glattfeld) 33. Organic Chemistry (advanced) (Glattfeld) DM. 2d Term Hours as for 4S.	2S. *General Inorganic Chemistry I* Mj. (Schlesinger) Lect.:[1] M., Tu., W. Lab.: *a* Tu., W., 9:00–10:00; Th., F. 8:00–10:00 *b* Th., F. 8:00–11:00 (*a* and *b* together limited to 100) *c* W., Th., F., 1:30–3:30 (limited to 50) *d* Th., F., 1:30–4:30 (together with *c* limited to 100) 4. *Elementary Organic Chemistry* Mj. (Glattfeld) Lect.:[1] W., Th., F. Lab.: *a* M., Tu., Sat. 8:00–10:00 *b* M., Tu., 8:00–11:00 *c* M., Tu., 1:30–4:30 (*a*, *b*, and *c* together limited to 100) 7. *Qualitative Analysis II* Mj. (Rising) Lect.:[1] Tu., F. Lab.: 8 hrs. per week	3S. *General Inorganic Chemistry II* Mj. (Schlesinger) Schedule as for 2S, Autumn Q. 7. *Qualitative Analysis II* Mj. Lect.: Tu., F. Lab.: 8 hrs. (Adler) 11. THEORIES AND METHODS OF QUANTITATIVE ANALYSIS ½Mj. 2 lectures weekly	4. *Elementary Organic Chemistry* Mj. (Glattfeld) Lect.: M., Tu., W. Lab.: *a* Th., F., Sat., 8:00–10:00 *b* Th., F., 8:00–11:00 *c* Th., F., 1:30–3:30 *d* W., Th., F., 1:30–4:30 (Limit of 100 for all sections together) 6. *Qualitative Analysis I* Mj. Lect.: M., Tu. Lab.: 8 hrs. per week (Rising)
9:00				20. ELEMENTARY PHYSICAL CHEMISTRY Mj. Lect.: W., Th., F. Lab.: M., Tu., 9:00–12:00 or 1:30–4:30 (Schlesinger)

NOTE.—Laboratory sections in courses 1, 2, 3, 2S, 3S, 4 for which at least 20 students are not registered will be withdrawn.

[1] For additional lectures at the regular period during the first or second week of the quarter, see the Quarterly Time Schedules.

TABULAR VIEW OF COURSES OFFERED BY THE DEPARTMENT OF CHEMISTRY, 1922–23—*Continued*

Hour	Summer, 1922	Autumn, 1922	Winter, 1923	Spring, 1923
10:00				1N. *Chemistry* (Primarily for Student Nurses) M. 1st Term Lect.: M., Tu., W. Lab.: Tu., F., 9:00–11:00 (This course may be withdrawn)
11:00	1. *Elementary General Chemistry I* DM. 1st Term 5 lectures weekly Lab.: M., Tu., W., Th. (Mullinix) 1:30–4:30 2. *Elementary General Chemistry II* DM. 2d Term Hours as for 1 (Mullinix) 20. Elementary Physical Chemistry Mj. Lect.: W., Th., F. Lab.: M., Tu. 9:00–12:00 or 1:30–4:30 (Harkins, 1st Term) (Dietrichson, 2d Term)	1. *Elementary General Chemistry I* Mj. (Terry) Lect.:[1] W., Th., F. Lab.: *a* M., Tu., 10:00–12:00; W., Th., 10:00–11:00 *b* M., Tu., 9:00–12:00 (*a* and *b* together limited to 50) *c* M., Tu., W., 1:30–3:30 (limited to 50) *d* M., Tu., 1:30–4:30 (*c* and *d* together limited to 75) 60.[2] Physical Chemistry I Mj. (Harkins) Lect.: W., Th., F. Lab.: Th., F., 1:30–4:30 or M., Tu., 9:00–12:00	2. *Elementary General Chemistry II* Mj. (Terry) Hours as for 1, Autumn Q. (Limit for sections *a* and *b*, 100, for *c*, 50, and for c and *d*, 100) 61.[2] Physical Chemistry II Mj. Schedule as for 60, Autumn, Q.	3. *Elementary General Chemistry III* Mj. Hours for 1, Autumn Q. (No limits) 62.[2] Physical Chemistry 3 Mj. (Harkins) 4 lectures per week
1:30	2S. *General Inorganic Chemistry I* DM. 1st Term 5 lectures weekly Lab.: M., Tu., W., Th. (Adler) 9:00–12:00 3S. *General Inorganic Chemistry II* DM. 2d Term Hours as for 2S (Adler) 6. *Qualitative Analysis I* Mj. (Stieglitz) Lect.:[1] M., Th. Lab.: 8 hrs. weekly 7. *Qualitative Analysis II* Mj. Lect.: Tu., F. Lab.: 8 hrs. weekly	6. *Qualitative Analysis I* Mj. Lect.:[1] M., Th. Lab.: 8 hrs. weekly (Rising)	6. *Qualitative Analysis I* Mj. Hours as for Autumn Q.[1] (Adler) 4. *Elementary Organic Chemistry* Mj. Lect.[1] W., Th., F. Lab.: M., Tu., 1:30–4:30 (Rising)	7. *Qualitative Analysis II* Mj. (Rising) Lect.: Tu., F. Lab.: 8 hrs. per week

[1] For additional lectures at the regular period in the first or second week of the quarter, see the Quarterly Time Schedule.

[2] Primarily for graduate students. Undergraduates are permitted to enter.

TABULAR VIEW OF COURSES OFFERED BY THE DEPARTMENT OF CHEMISTRY, 1922–23—*Continued*

Hour	Summer, 1922	Autumn, 1922	Winter, 1923	Spring, 1923
2:30	8. Quantitative Analysis I Mj. or DM. Lect.:[1] Th. (Noyes) Lab.: 8 hrs. weekly[2] 8M. Quantitative Analysis (primarily for Medical Students) ½Mj. or M. Lect.:[1] Th. (Noyes) Lab.:[2] 4 hrs. weekly 9. Quantitative Analysis II Mj. or DM. Lect.:[1] Tu. (Noyes) Lab.:[2] 8 hrs. weekly	8. Quantitative Analysis I (Noyes) Mj. See Summer Q. for hours 8M. Quantitative Analysis (primarily for Medical Students) (Noyes) ½Mj. See Summer Q. for hours 9. Quantitative Analysis II (Noyes) Mj. Hours as for Summer Q.		8. Quantitative Analysis II (Adler) Mj. Hours as in Summer Q. 8M. Quantitative Analysis (primarily for Medical Students) (Adler) ½Mj Hours as in Summer Q. 9. Quantitative Analysis II (Adler) Mj. Hours as in Summer Q.
3:30			8. Quantitative Analysis I (Noyes) Mj. Lect.:[1] Th., at 3:30 Lab.:[2] 8 hrs. weekly 8M. Quantitative Analysis (for Medical Students) (Noyes) ½Mj. Lect.:[1] Th., at 3:30 Lab.:[2] 8 hrs. weekly 9. Quantitative Analysis II (Noyes) Mj. Lect.:[2] Tu., at 3:30 Lab.:[1] 8 hrs. weekly	
4:30		30.[3] Organic Chemistry. Mj. (Stieglitz) Lect.: M., Tu., W. Lab.: Th., F., 8:00–11:00 or 1:30–4:30	31.[3] Organic Chemistry Mj. (Stieglitz) Lect.: Tu., W. Lab.: Th., F., P.M. 2 hrs. each day	32.[3] Organic Chemistry Mj. (Nicolet) Lect.: Tu., W. Lab.: Th., F., 2:30–5:30

[1] For additional lectures at the regular period during the first or second week of the quarter, see the Quarterly Time Schedule.
[2] For consultation hours for laboratory work see Quarterly Time Schedules.
[3] Primarily for graduate students. Undergraduates are permitted to enter.

TABULAR VIEW OF COURSES OFFERED BY THE DEPARTMENT OF CHEMISTRY, 1922–23

PART II.—More advanced courses and laboratory courses. For the hours of these courses, see the Quarterly Time Schedules. Senior College courses are in capitals; Graduate courses are in Roman type.

Summer, 1922	Autumn, 1922	Winter, 1923	Spring, 1923
10. ADVANCED QUALITATIVE ANALYSIS Mj. or DM. Lab.: 10 or 20 hrs. per week	12–19. SPECIAL METHODS IN QUANTITATIVE ANALYSIS ½Mj. or Mj. Lab. courses. For details see departmental circular (Noyes)	10. ADVANCED QUALITATIVE ANALYSIS Mj. Lab.: 10 hrs. a week (Adler)	10. ADVANCED QUALITATIVE ANALYSIS Mj. (Rising) Lab.: 10 hrs. a week
12–19. SPECIAL METHODS IN QUANTITATIVE ANALYSIS ½Mj., M., or DM. Lab. courses. For details, see departmental circular (Noyes)	35[1], 36, 37. Each 1 Mj. Lab.: 10 hrs. per week (Nicolet)	12–19. SPECIAL METHODS OF QUANTITATIVE ANALYSIS ½Mj. or Mj. Lab. courses. For details, see departmental circular (Noyes)	12–19. SPECIAL METHODS OF QUANTITATIVE ANALYSIS ½Mj. or Mj. Lab. course. For details, see departmental circular (Adler)
35,[1] 36, 37. Organic Preparations Each Mj. or DM. Lab.: 10 or 20 hrs. weekly (Glattfeld)	39. Organic Elementary Analysis ½Mj. (Nicolet) Lab.: 60 hrs. per quarter	35[1], 36, 37. Organic Preparations Each 1Mj. (Nicolet) Lab.: 10 hrs. weekly	35,[1] 36, 37. Organic Preparations Each 1Mj. (Nicolet) Lab.: 10 hrs. per week
38. Qualitative Organic Analysis Mj. (Kharasch) Lect.: 2 hrs. per week Lab.: 8 hrs. per week	46. Special Topics of Organic Chemistry ½Mj. 2 lect. weekly (Nicolet)	39. Organic Elementary Analysis ½Mj. (Rising) Lab.: 60 hrs. per quarter	39. Organic Elementary Analysis ½Mj. (Glattfeld) Lab.: 60 hrs. per quarter
39. Organic Elementary Analysis ½Mj. Lab. work 60 hrs. per quarter. (Stieglitz)	48. Electrolytic Processes in Organic Chemistry Mj. 2 lect., 7 hrs. of lab. per week (Terry)	41. Stereochemistry ½Mj. (Rising) 2 lect. a week	40C. Organic Dyestuffs ½Mj. 2 lect. weekly (Kharasch)

[1] Informal class meetings accompany the laboratory work.

TABULAR VIEW OF COURSES OFFERED BY THE DEPARTMENT OF CHEMISTRY, 1922–23—*Continued*

Summer, 1922	Autumn, 1922	Winter, 1923	Spring, 1923
45. Selected Topics of Organic Chemistry M. 1st T. (Stieglitz) Lect.: 4 hrs per week	63. Physico-Chemical Measurements Mj. Lab.: 10 hrs. per week (Harkins) 75. Subatomic Phenomena and Radioactivity ½Mj. 2 lect. weekly (Harkins)	50[1], 51, 52. Inorganic Preparations Each 1 Mj. (Schlesinger) Lab.: 10 hrs. a week	42. Carbohydrates ½Mj. 2 lect. weekly (Glattfeld)
46A. Special Topics of Organic Chemistry, Aromatic Series M. 2d T. (Hanke) Lect.: 4 hrs. per week	90–98. Research	55A. Advanced Inorganic Chemistry ½Mj. (Schlesinger) 2 lect. per week	50[1], 51, 52. Inorganic Preparations Each 1Mj. (Schlesinger) Lab.: 10 hrs. per week
50,[1] 51, 52. Inorganic Preparations Mj., or M., or DM. either Term Lab.: 10 or 20 hrs. weekly (1st T., Harkins; 2d T., Franklin)		63. Physico-Chemical Measurements Mj. (Harkins) Lab.: 10 hrs. a week 76. Laboratory Course in Radioactivity ½Mj. To follow course 75 (Harkins)	55C. Advanced Inorganic Chemistry ½Mj. 2 lect. weekly (Schlesinger)
56. The Chemistry of Non-Aqueous Systems 2d T. 2 lect. weekly (Franklin)		90–98. Research	
63. Physico-Chemical Measurements. (M. or DM. 2d T.) (Dietrichson) Lab.: 10 or 20 hrs. per week.			
90–98. Research			90–98. Research

[1] Informal class meetings accompany the laboratory work.

DOCTORS OF PHILOSOPHY OF THE UNIVERSITY OF CHICAGO

MATHEMATICS[1]

1896 Leonard Eugene Dickson, Professor of Mathematics, University of Chicago, Chicago, Ill.
The Analytic Representation of Substitutions on a Power of a Prime Number of Letters with a Discussion of the Linear Group.

John Irwin Hutchinson, Professor of Mathematics, Cornell University, Ithaca, N.Y.
On the Reduction of Hyperelliptic Functions ($p=2$) to Elliptic Functions by a Transformation of the Second Degree.

1898 Herbert Ellsworth Slaught, Professor of Mathematics, University of Chicago, Chicago, Ill.
The Cross-Ratio Group of 120 Quadratic Cremona Transformations of the Plane.

1899 John Anthony Miller, Professor of Mathematics and Astronomy, Swarthmore College, Swarthmore, Pa.
Concerning Certain Elliptic Modular Functions of Square Rank.

1900 Gilbert Ames Bliss, Professor of Mathematics, University of Chicago, Chicago, Ill.
The Geodesic Lines on the Anchor Ring.

George Lincoln Brown, Professor of Mathematics, South Dakota Agricultural College, Brookings, S.D.
A Ternary Linear Substitution Group of Order 3.360.

William Gillespie, Professor of Mathematics, Princeton University, Princeton, N.J.
On the Reduction of Hyperelliptic Integrals ($p=3$) to Elliptic Integrals by Transformation of the Second and Third Degree.

Derrick Norman Lehmer, Associate Professor of Mathematics, University of California, Berkeley, Cal.
Asymptotic Evaluation of Totient Sums.

John Hector McDonald, Assistant Professor of Mathematics, University of California, Berkeley, Cal.
On the System of a Binary Cubic and Quadratic and the Reduction of Hyperelliptic Integrals of Genus Two to Elliptic Integrals by a Transformation of the Fourth Order.

Ernest Brown Skinner, Professor of Mathematics, University of Wisconsin, Madison, Wis.
Ternary Monomial Substitution Groups of Finite Order with Determinant $\doteq 1$.

1901 William Findlay, Professor of Mathematics, McMaster University, Toronto, Ont.
The Sylow Subgroups of the Symmetric Group.

Thomas Milton Putnam, Professor of Mathematics and Dean of the Lower Division, University of California, Berkeley, Cal.
The Quaternary Linear Homogeneous Group and the Ternary Linear Fractional Group.

1903 Oswald Veblen, Professor of Mathematics, Princeton University, Princeton, N.J.
A System of Axioms for Geometry.

[1] The title of the dissertation submitted for the doctorate is printed after each name.

1904 William Henry Bussey, Professor of Mathematics and Dean in the College of Science, University of Minnesota, Minneapolis, Minn.
Generational Relations for the Abstract Group Simply Isomorphic with the Group LF(2; p^n).

Herbert Edwin Jordan, Assistant Professor of Mathematics, University of Kansas, Lawrence, Kan.
Group Characters of Various Linear Groups.

Arthur Whipple Smith, Professor of Mathematics and Head of the Department, Colgate University, Hamilton, N.Y.
Symbolic Treatment of Differential Geometry.

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Concerning a Certain Type of Continued Fractions Depending on a Variable Parameter.

Robert Lee Moore, Associate Professor of Mathematics, University of Texas, Austin, Tex.
Sets of Metrical Hypotheses for Geometry.

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A Class of Periodic Orbits of an Infinitesimal Body Subject to the Attraction of n Finite Bodies.

Arthur Ranum, Assistant Professor of Mathematics, Cornell University, Ithaca, N.Y.
The Group of Classes of Congruent Matrices with Application to the Group of Ismorphisms of Any Abelian Group.

Anthony Lispenard Underhill, Associate Professor of Mathematics, University of Minnesota, Minneapolis, Minn.
Invariants under Point Transformations in the Calculus of Variations.

Buzz M. Walker, Professor of Mathematics, Dean of School of Engineering, Vice-President Mississippi Agricultural and Mechanical College, Agricultural College, Miss.
On the Resolution of Higher Singularities of Algebraic Curves into Ordinary Double Points.

1907 George David Birkhoff, Professor of Mathematics, Harvard University, Cambridge, Mass.
Asymptotic Properties of Certain Ordinary Differential Equations, with Applications to Boundary Value and Expansion Problems.

Robert Lacy Börger, Professor of Mathematics, Ohio University, Athens, Ohio.
On the Determination of Ternary Linear Groups in the Galois Field of Order p^2.

Louis Ingold, Assistant Professor of Mathematics, University of Missouri, Columbia, Mo.
Vector Interpretation of Symbolic Parameters.

Nels Johann Lennes, Professor of Mathematics and Head of the Department, University of Montana, Missoula, Mont.
Curves in Non-metrical Analysis Situs with an Application in the Calculus of Variations.

Frederick William Owens, Assistant Professor of Mathematics, Cornell University, Ithaca, N.Y.
The Introduction of Ideal Elements and Construction of Projective n-space in Terms of a Planar System of Points.

Norman Richard Wilson, Professor of Mathematics, University of Manitoba, Winnipeg, Canada.
Isoperimetrical Problems Which Are Reducible to Non-isoperimetrical Problems.

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On a Compound Discontinuous Solution Connected with the Surface of Revolution of Minimum Area.

1909 Thomas Buck, Assistant Professor of Mathematics, University of California, Berkeley, Cal.
Oscillating Satellites near the Lagrangian Equilateral Triangular Points.

Arnold Dresden, Associate Professor of Mathematics, University of Wisconsin, Madison, Wis.
The Second Derivatives of the Extremal-Integral.

Harris Franklin MacNeish, Assistant Professor of Mathematics, College of the City of New York, New York, N.Y.
Linear Polars of the k-hedron in n-space.

1910 Richard Philip Baker, Associate Professor of Mathematics, State University of Iowa, Iowa City, Iowa.
The Problem of the Angle-Bisectors.

William Hunt Bates, Associate Professor of Mathematics, Purdue University, Lafayette, Ind.
An Application of Symbolic Methods of the Treatment of Mean Curvatures in Hyper-Space.

Theophil Henry Hildebrant, Associate Professor of Mathematics, University of Michigan, Ann Arbor, Mich.
A Contribution to the Foundations of Fréchet's Calcul Fonctionnel.

Egbert J. Miles, Assistant Professor of Mathematics, Yale University, New Haven, Conn.
The Absolute Minimum of a Definite Integral in a Special Field.

Anna Johnson Pell, Associate Professor of Mathematics, Bryn Mawr College, Bryn Mawr, Pa.
I. Biorthogonal Systems of Functions. II. Application to the Theory of Integral Equations.

Arthur Dunn Pitcher, Professor of Mathematics, Western Reserve University, Cleveland, Ohio.
The Interrelation of Eight Fundamental Properties of Classes of Functions.

Marion Ballantyne White, Professor of Mathematics, Carleton College, Northfield, Minn.
The Dependence of the Focal Point on Curvature in Space Problems of the Calculus of Variations.

1911 Lloyd Lyne Dines, Professor of Mathematics, University of Saskatchewan, Saskatoon, Canada.
The Highest Common Factor of a System of Polynomials, with an Application to Implicit Functions.

Theodore Lindquist, Professor of Mathematics, State Normal School, Emporia, Kan.
Mathematics for Freshman Students of Engineering.

Ralph Eugene Root, Professor of Mathematics, U.S. Naval Academy, Annapolis, Md.
Iterated Limits in General Analysis.

Albert Harris Wilson, Associate Professor of Mathematics, Haverford College, Haverford, Pa.
The Canonical Types of Nets of Quadratic Forms in the Galois Field of Order p^a.

1912 Edward Wilson Chittenden, Associate Professor of Mathematics, State University of Iowa, Iowa City, Iowa.
Infinite Developments and the Composition Property $(K_{12}B_1)_*$ in General Analysis.

1912 Charles Albert Fischer, Professor of Mathematics and Astronomy, Trinity College, Hartford, Conn.
Some Contributions to the Theory of Functions of Lines.

Charles Thompson Sullivan, Associate Professor of Mathematics, McGill University, Montreal, Canada.
Properties of Surfaces Whose Asymptotic Lines Belong to Linear Complexes.

1913 William Charles Krathwohl, Associate Professor of Mathematics, Armour Institute of Technology, Chicago, Ill.
Modular Invariants of Two Pairs of Cogredient Variables.

Wilson Lee Miser, Associate Professor of Mathematics, Armour Institute, Chicago, Ill.
On Linear Homogeneous Differential Equations with Elliptic Function Coefficients.

†Frank Marion Morrison.
On the Relation between Some Important Notions of Projective and Metrical Differential Geometry.

Elton James Moulton, Professor of Mathematics, Northwestern University, Evanston, Ill.
On Figures of Equilibrium of a Rotating Heterogeneous Fluid Body.

†Mildred Leonora Sanderson.
Formal Modular Invariants with an Application to Binary Modular Covariants.

1914 Myer Grupp Gaba, Assistant Professor of Mathematics, University of Nebraska, Lincoln, Neb.
A Set of Postulates for General Projective Geometry of n Dimensions.

Harold Reynolds Kingston, Professor of Mathematics, Western University, London, Ontario, Canada.
Metric Properties of Nets of Plane Curves.

William Vernon Lovitt, Professor of Mathematics, Colorado College, Colorado Springs, Colo.
A Type of Singular Points for a Transformation of Three Variables.

Forbes Bagley Wiley, Professor of Mathematics, Denison University, Granville, Ohio.
Proof of the Finiteness of Modular Covariants of a System of Binary Form of Cogredient Points.

1915 Allen Fuller Carpenter, Associate Professor of Mathematics, University of Washington, Seattle, Wash.
Ruled Surfaces Whose Flecnode Curves Have Plane Branches.

Charles Ross Dines, Federal Reserve Bank, Chicago, Ill.
Functions of Positive Type and Selected Topics in General Analysis.

Jasper Ole Hassler, Associate Professor of Mathematics, University of Oklahoma, Norman, Okla.
Plane Nets Periodic of Period Three under the Laplace Transformation.

Olive Clio Hazlett, Assistant Professor of Mathematics, Mount Holyoke College, South Hadley, Mass.
On the Classification and Invariantive Characterizations of Nilpotent Algebras.

Archibald Henderson, Professor of Mathematics, University of North Carolina, Chapel Hill, N.C.
The Twenty-seven Lines upon the Cubic Surface.

Alfred Lewis Nelson, Assistant Professor of Mathematics, University of Michigan, Ann Arbor, Mich.
Plane Nets with Equal Laplace-Darboux Invariants.

† Deceased.

1915 Vincent Collins Poor, Assistant Professor of Mathematics, University of Michigan, Ann Arbor, Mich.
A Certain Type of Exact Solution of the Equations of Motion of a Viscous Liquid.

Samuel Watson Reaves, Professor of Mathematics, University of Oklahoma, Norman, Okla.
Metric Properties of Flecnodes on Ruled Surfaces.

Mary Evelyn Wells, Assistant Professor of Mathematics, Vassar College, Poughkeepsie, N.Y.
The Determination of All Inequalities of Certain Types in General Linear Integral Equation Theory.

Chester Henry Yeaton, Assistant Professor of Mathematics, Oberlin College, Oberlin, Ohio.
Surfaces Characterized by Certain Properties of Their Directrix Congruences.

1916 Elmer Daniel Grant, Professor of Mathematics, Earlham College, Richmond, Ind.
The Motion of a Flexible Cable in a Vertical Plane.

Arthur McCracken Harding, Professor of Mathematics, University of Arkansas, Fayetteville, Ark.
On Certain Loci Projectively Connected with a Given Plane Curve.

William Leroy Hart, Associate Professor of Mathematics, University of Minnesota, Minneapolis, Minn.
Differential Equations and Implicit Functions in Infinitely Many Variables.

Gillie Aldah Larew, Professor of Mathematics, Randolph-Macon Woman's College, Lynchburg, Va.
Necessary Conditions for the Problem of Mayer in the Calculus of Variations.

Arthur Shepard Merrill, Associate Professor of Mathematics, University of Montana, Missoula, Mont.
An Isoperimetric Problem with Variable End-Points.

Arthur Richard Schweitzer, Chicago, Ill.
Les Idées directrices de la logique génétique des mathématiques.

David Melville Smith, Associate Professor of Mathematics, Georgia School of Technology, Atlanta, Ga.
Jacobi's Condition for the Problem of Lagrange in the Calculus of Variations.

Pauline Sperry, Instructor in Mathematics, University of California, Berkeley, Cal.
Properties of a Certain Projectively Defined Two-Parameter Family of Curves on a General Surface.

1917 Jacob Millison Kinney, Instructor in Mathematics, Crane Junior College, Chicago, Ill.
The General Theory of Congruences without Any Preliminary Integration.

Kenneth Worcester Lamson, Instructor in Mathematics, Columbia University, New York, N.Y.
A General Implicit Function Theorem, with an Application to Problems of Relative Minimum.

Flora Elizabeth Le Stourgeon, Assistant Professor of Mathematics, University of Kentucky, Lexington, Ky.

†James Elijah McAtee.
Modular Invariants of a Quadratic Form for a Prime Power Modulus.

† Deceased.

1917 William Pinkerton Ott, Associate Professor of Mathematics, Vanderbilt University, Nashville, Tenn.
The General Problem of the Type of the Brachistochrone with Variable End-Points.

Levi Stephen Shively, Professor of Mathematics and Acting President, Mount Morris College, Mount Morris, Ill.
A New Basis for the Metric Theory of Congruences.

Thomas McNider Simpson, Jr., Professor of Mathematics, Randolph-Macon College, Ashland, Va.
Relation between the Metric and Projective Theories of Space Curves.

1918 Israel Albert Barnett, Assistant Professor of Mathematics, University of Saskatchewan, Saskatoon, Canada.
Differential Equations with a Continuous Infinitude of Variables.

George Hoffman Cresse, Associate Professor of Mathematics, University of Arizona, Tuczon, Ariz.
On the Class Numbers of Binary Quadratic Forms.

Ernest Preston Lane, Assistant Professor of Mathematics, University of Wisconsin, Madison, Wis.
Conjugate Systems with Indeterminate Axis Curves.

Webster Godman Simon, Assistant Professor of Mathematics, Western Reserve University, Cleveland, Ohio.
On the Solution of Certain Types of Linear Differential Equations in Infinitely many variables.

1919 Cyril Arthur Nelson, Associate in Mathematics, Johns Hopkins University, Baltimore, Md.
Conjugate Systems with Conjugate Axis Curves.

1920 Gladys Elizabeth Carson Gibbens, Instructor in Mathematics, University of Minnesota, Minneapolis, Minn.
Comparison of Different Line Geometric Representations for Functions of a Complex Variable.

John Wayne Lasley, Jr., Associate Professor of Mathematics, University of North Carolina, Chapel Hill, N.C.
Some Special Cases of the Flecnode Transformations of Ruled Surfaces.

Irwin Roman, Instructor in Mathematics, Northwestern University, Evanston, Ill.
The Transformation of Waves through a Symmetrical Optical Instrument.

William Lloyd Garrison Williams, Instructor in Mathematics, Cornell University, Ithaca, N.Y.
Fundamental System of Formal Modular Simi-Invariants of the Binary Cubic.

Frank Edwin Wood, Assistant Professor of Mathematics, Michigan Agricultural College, Lansing, Mich.
On Certain Relations between the Projective Theory of Surfaces and the Projective Theory of Congruences.

1921 Edward Hegeler Carus, President of the Carus Chemical Company, LaSalle, Ill.
Invariants as Products: A Vector Interpretation of the Symbolic Method.

Claribel Kendall, Instructor in Mathematics, University of Colorado, Boulder, Colo.
Certain Congruences Determined by a given Surface.

1921 Mayme Irwin Logsdon, Instructor in Mathematics, University of Chicago, Chicago, Ill.
Equivalents and Reduction of Pairs of Hermitian Forms.

Cyrus Colton MacDuffee, Instructor in Mathematics, Princeton University, Princeton, N.J.
Invariantive Characterizations of Linear Algebras with the Associative Law Not Assumed.

MATHEMATICAL ASTRONOMY

1900 Forest Ray Moulton, Professor of Astronomy, University of Chicago, Chicago, Ill.
Periodic Oscillating Satellites.

1903 William Albert Hamilton, Professor of Astronomy, Beloit College, Beloit, Wis.
The True Radii of Convergence for Expansions as Power Series in the Time, in the Case of Parabolic Motion.

1904 Arthur Constant Lunn, Associate Professor of Applied Mathematics, University of Chicago, Chicago, Ill.
The Differential Equations of Dynamics.

1905 Delonzo Tate Wilson, Associate Professor of Mathematics, Case School of Applied Science, Cleveland, Ohio.
Work on Minor Planets.

1906 Frank Loxley Griffin, Professor of Mathematics, Reed College, Portland, Ore.
Certain Periodic Orbits of k Finite Bodies Revolving about a Relatively Large Central Mass.

1908 William Duncan MacMillan, Associate Professor of Astronomy, University of Chicago, Chicago, Ill.
Periodic Orbits about an Oblate Spheroid.

1909 Herbert Earle Buchanan, Professor of Mathematics, Tulane University, New Orleans, La.
Periodic Oscillations of Three Finite Masses about the Langrangian Circular Solutions.

1911 Daniel Buchanan, Professor of Mathematics, University of British Columbia, Vancouver, B.C.
A Class of Periodic Solutions of the Problem of Three Bodies, Two of Equal Mass, the Third Moving on a Straight Line.

1913 Lloyd Arthur Heber Warren, Professor of Mathematics, University of Manitoba, Winnipeg, Canada.
A Class of Asymptotic Orbits in the Problem of Three Bodies.

1915 John William Campbell, Assistant Professor of Mathematics, University of Alberta, Edmonton, Alberta.
Periodic Solution of the Problem of Three Bodies in Three Dimensions.

Louis Allen Hopkins, Assistant Professor of Mathematics, University of Michigan, Ann Arbor, Mich.
On the Theory of the Motion of the Small Planets with a Periodic Orbit for the Hilda Type.

PRACTICAL ASTRONOMY AND ASTROPHYSICS

1913 Curvin Henry Gingrich, Professor of Astronomy, Carleton College, Northfield, Minn.
A Determination of the Photographic Magnitudes of Comparison Stars in Certain Hagen Fields.

1913 Oliver Justin Lee, Instructor in Practical Astronomy, Yerkes Observatory, Williams Bay, Wis.
The Spectroscopic System 9 Camelopardalis.

1914 Frank Craig Jordan, Professor of Astronomy, University of Pittsburgh, Pittsburgh, Pa.
The Color-Changes of Certain Variable Stars of Short Periods.

1915 Harlan True Stetson, Assistant Professor, Students' Astronomical Laboratory, Harvard University, Cambridge, Mass.
On the Apparatus and on Methods for Thermo-electric Measurements in Photographic Photometry, with Application to the Determination of Magnitude, Spectral Intensities, and the Light Curves of Variable Stars.

1917 Edwin Powell Hubble, Assistant, Mount Wilson Observatory, Pasadena, Cal.
Photographic Investigations of Faint Nebulae.

1919 Hannah Steele Pettit, Pasadena, Cal.
The Proper Motions and Parallaxes of 359 Stars in the Cluster h Persei, Derived from Photographs Made with the 40-Inch Refractor of the Yerkes Observatory.

1920 Alice Hall Farnsworth, Instructor in Astronomy, Mount Holyoke College, South Hadley, Mass.
Comparison of the Photometric Fields of the 6-Inch Doublet, 24-Inch Reflector, and 40-Inch Refractor with Some Investigation of the Astrometric Field of the Reflector.

Edison Pettit, Assistant, Mount Wilson Observatory, Pasadena, Cal.
The Form and Motions of the Solar Prominences.

1921 Harriet McWilliams Parsons, Instructor in Astronomy, Smith College, Northampton, Mass.
Astrometric and Photometric Statistics of Certain of Hagen's Fields Photographed with the Two-Foot Reflector of the Yerkes Observatory.

PHYSICS

1897 Gordon Ferry Hull, Professor of Physics, Dartmouth College, Hanover, N.H.; Major in Ordnance, U.S.A.
On the Use of the Interferometer in the Study of Electric Waves.

Isabel Stone, Principal of American School for Girls, Rome, Italy.
On the Electrical Resistance of Thin Films.

1898 Edwin Sheldon Johonnott, Professor of Physics, Rose Polytechnic Institution, Terre Haute, Ind.
Thickness of the Black Spot in Liquid Films.

1899 Henry Gordon Gale, Professor of Physics, University of Chicago, Chicago, Ill.
On the Relation between Density and Index of Refraction of Air.

1900 Robert Francis Earhart, Professor of Physics, Ohio State University, Columbus, Ohio.
The Sparkling Potentials between Plates at Small Distances.

1901 Fritz Reichmann, Practical Physicist, Troy, N.Y.
The Capacities of Air Condensers for Very Small Distances between the Plates.

1902 Frank Baldwin Jewett, Vice-President and Chief Engineer, Western Electric Co., New York, N.Y.
A New Method of Determining the Vapor-Density of Metallic Vapors.

1904 Thomas Eaton Doubt, Professor of Physics, Armour Institute of Technology, Chicago, Ill.
The Effect of Intensity upon the Velocity of Light.

1904 Fannie Cornelia Frisbee (Mrs. Frank B. Jewett), Short Hills, N.J.
The Effects of Pressure on Magnetic Induction.

Thomas Carlyle Hebb, Professor of Physics, University of British Columbia, Vancouver, Canada.
The Velocity of Sound.

1905 Frederic Lendhall Bishop, Professor of Physics, University of Pittsburgh, Pittsburgh, Pa.
The Thermal Conductivity of Lead.

Glenn Moody Hobbs, Manager of Testing Laboratory, Sears Roebuck & Co., Chicago, Ill.
The Relation between P.D. and Spark-Length for Small Values of the Latter.

Carleton John Lynde, Professor of Physics, MacDonald College, Quebec, Canada.
The Effect of Pressure on Surface Tension.

1906 William Richards Blair, Major, Signal Corps, U.S. Army, in charge Meteorological Division, Washington, D.C.
The Change of Phase Due to the Passage of Electric Waves through Thin Films.

Lawrence Emery Gurney, Professor of Physics, University of the Philippines, Manila, P.I.
The Viscosity of Water at Low Rate of Shear.

1907 Oliver Charles Clifford, Professor of Electrical Engineering, Armour Institute of Technology, Chicago, Ill.
Susceptibility of Copper and Tin and Their Alloys.

George Winchester, Professor of Physics, Rutgers College, New Brunswick, N.J.
Discharge of Electricity from Metals under the Influence of Ultra-Violet Light.

1909 William Ross Ham, Professor of Physics, Pennsylvania State College, State College, Pa.
The Polarization of Primary X-Rays.

Charles Albert Proctor, Professor of Physics, Dartmouth College, Hanover, N.H.
The Variation of $\frac{e}{m}$ with Speed in the Case of Cathode Rays.

Newland Farnsworth Smith, Professor of Physics, The Military College of South Carolina, The Citadel, Charleston, S.C.
Effect of Tension on Thermal and Electrical Conductivity.

1910 Louis Begeman, Professor of Physics, Iowa State Teachers College, Cedar Falls, Iowa.
The Determination of "e" by the Cloud Method.

J. Harry Clo, Professor of Physics, University of Pittsburgh, Pittsburgh, Pa.
The Effect of Temperature upon the Ionization of Gas.

Ansel Alphonso Knowlton, Professor of Physics, Reed College, Portland, Ore.
Preparation and Testing of Heusler Alloys.

John Mathias Kuehne, Professor of Physics, University of Texas, Austin, Tex.
The Electrostatic Effect of a Changing Magnetic Field.

James Remus Wright, Research Physicist, Standard Oil Co. of Indiana, Whiting, Ind.
Photo-electric Effects of Aluminum as a Function of the Wave-Length of the Incident Light.

1911 HAROLD DE FOREST ARNOLD, Head of Research Laboratory, Western Electric Co., New York, N.Y.
Limitations Imposed by Slip and Inertia Terms upon Stokes Law for the Motion of Spheres through Liquids.

†EDWIN SHERWOOD BISHOP.
A Determination of the Minimum Ionizing Kinetic Energy of an Electron in a Gas.

HARVEY FLETCHER, Research Laboratory, Western Electric Co., New York, N.Y.
A Verification of the Theory of Brownian Movements and a Direct Determination of the Value of "Ne" for Gaseous Ionization.

HARVEY BRACE LEMON, Associate Professor of Physics, University of Chicago, Chicago, Ill.
The Influence of Temperature upon the Intensities of the Lines of the Hydrogen Spectrum.

HOWARD WILSON MOODY, Professor of Physics, Mississippi Agricultural College, Agricultural College, Miss.
A Determination of the Ratio of the Specific Heats and the Specific Heat at Constant Pressure of Air and Carbon Dioxide.

1913 LACHLAN GILCHRIST, Assistant Professor of Physics, University of Toronto, Toronto, Ontario, Canada.
An Absolute Determination of the Viscosity of Air.

EDWARD JAMES MOORE, Professor of Physics, University of Buffalo, Buffalo, N.Y.
Reaction Effects Produced by the Discharge of Electricity from Points in Gases and the Bearing of These Effects on the Theory of the Small Ion.

1914 ALBERT EDWARD HENNINGS, Professor of Physics, University of British Columbia, Vancouver, B.C.
A Study of the Contact Potentials and Photo-electric Properties of Metals *in Vacuo*.

VERNE FRANK SWAIM, Professor of Physics, Bradley Polytechnic Institute, Peoria, Ill.
The Pressure-Shift of Lines in the Spectrum of Zinc.

1915 WILLIAM HENRY KADESCH, Professor of Physics, Iowa State Teachers' College, Cedar Falls, Iowa.
The Energy of Photo-Electrons from Sodium and Potassium as a Function of the Frequency of the Incident Light.

JOHN YIU-BONG LEE, Head of Lecture Department, Y.M.C.A. in China, 20 Museum Road, Shanghai, China.
The Determination of "e" by the Millikan Method Using Solid Spheres.

ISAIAH MARCH RAPP, Professor of Physics, University of Montana, Missoula, Mont.
The Flow of Air through Capillary Tubes.

OSCAR WILLIAM SILVEY, Professor of Physics, Texas Agricultural and Mechanical College, College Station, Tex.
A Comparison of the Fall of a Droplet in a Liquid and in a Gas.

1916 ARTHUR JEFFERY DEMPSTER, Assistant Professor of Physics, University of Chicago, Chicago, Ill.
The Properties of Slow Canal Rays.

ERTLE LESLIE HARRINGTON, Professor of Physics, University of Saskatchewan, Saskatoon, Canada.
A Redetermination of the Absolute Value of the Coefficient of Viscosity of Air.

† Deceased.

1916 Yoshio Ishida, Physicist, Imperial Institute, Tokyo, Japan.
The Kinetic Theory of Rigid Molecules.

Leonard B. Loeb, National Research Fellow in Physics, University of Chicago, Chicago, Ill.
Mobility of Gaseous Ions in High Electric Fields.

Carl Danforth Miller, Associate Professor of Physics, University of Manitoba, Winnipeg, Canada.
Absorption Coefficients of Soft X-Rays.

Benjamin Estill Shackelford, Physicist, The Westinghouse Co., New York, N.Y.
Temperature and Blackening Effects in Helical Tungsten Filaments.

William Henry Souder, Physicist, Bureau of Standards, Washington, D.C.
The Normal Photo-electric Effect of Lithium, Sodium, and Potassium as a Function of Wave-Lengths and Incidental Energy.

Walter Ticknor Whitney, Assistant Professor of Physics, California Institute of Technology, Pasadena, Cal.
The Pole Effect in a Calcium Arc.

1917 Karl Kelchner Darrow, Research Physicist, Western Electric Co., New York, N.Y.
Preliminary Report on a New Method for Determining the Velocity of Sound in Gases.

Victor Hugo Gottschalk, Chemist, American Cotton and Oil Co., Chicago, Ill.
The Nature of the Process of Ionization by Alpha Rays.

Leopold Joseph Lassalle, Professor of Mechanical Engineering, University of Louisiana, Baton Rouge, La.
The Law of Fall of a Sphere through Carbon Dioxide and an Exact Determination of the Viscosity of That Gas.

Margaret Calderwood Shields, Associate Professor of Physics, Mount Holyoke College, South Hadley, Mass.
A Determination of the Ratio of the Specific Heats of Hydrogen at 18 Degrees and −190 Degrees.

1919 John Bewley Derieux, Associate Professor of Physics, North Carolina State College, Raleigh, N.C.
I. The Use of Mercury Droplets in Millikan's Experiment.
II. Photo-Electric Effects on Mercury Droplets.

Charles Frederick Hagenow, Associate Professor of Physics, Washington University, St. Louis, Mo.
Thermionic and Photoelectric Phenomena at the Lowest Attainable Pressures.

Mervin Joe Kelly, Research Physicist, Western Electric Research Laboratory, New York, N.Y.
The Valency of Photo-Electrons and the Photo-electric Properties of Some Insulators.

Harold W. Nichols, Theoretical Physicist, Western Electric Research Laboratory, New York, N.Y.
Theory of Variable Dynamical-Electrical Systems.

Ralph Alanson Sawyer, Instructor in Physics, University of Michigan, Ann Arbor, Mich.
Metallic Spark Spectra in the Extreme Ultra-Violet.

Leland Johnson Stacy, Telephone Development Engineer, Western Electric Co., New York, N.Y.
A Determination by the Constant-Deflection Method of the Value of the Coefficient of Slip for Rough and for Smooth Surfaces in Air.

1920 Ira Garnett Barber, Research Physicist, American Chicle Co., Long Island City, N.Y.
Secondary Electron Emission from Copper Surfaces.

Oswald Blackwood, Assistant Professor of Physics, University of Pittsburgh, Pittsburgh, Pa.
On the Existence of Homogeneous Groups of Large Ions.

Otto Koppius, Assistant Professor of Physics, Oberlin College, Oberlin, Ohio.
A Comparison of the Thermionic and Photoelectric Work-Functions in Platinum.

Harold Horton Sheldon, Instructor in Physics, University of Michigan, Ann Arbor, Mich.
Charcoal Activation.

1921 William Kunerth, Associate Professor of Physics, Iowa State College of Agriculture and Mechanical Arts, Ames, Iowa.
The Solubility of CO_2 and N_2O in Certain Solvents.

Louallen Fredrick Miller, Assistant Professor of Physics, University of Minnesota, Minneapolis, Minn.
Pressure Shifts in a Calcium Arc.

John Preston Minton, National Research Fellow in Physics, University of Chicago, Chicago, Ill.
Sensitivity of Normal and Defective Ears for Tones of Various Frequencies.

William Ralph Smythe, Assistant Professor of Physics, University of the Philippines, Manila, P.I.
The Spectrum of Fluorine.

Karl Skillman VanDyke, Assistant Professor of Physics, Wesleyan University, Middletown, Conn.
A Determination of the Coefficients of Viscosity and of Slip for Carbondioxide and Air by the Constant-Deflection Method.

Hugo Bernard Wahlin, Instructor in Physics, University of Wisconsin, Madison, Wis.
Behavior of Free Electrons toward Gas Molecules.

Thomas Russell Wilkins, Professor of Physics, Brandon College, Brandon, Manitoba, Canada.
Multiple Valency in the Ionization by Alpha Rays.

CHEMISTRY

1894 Adolph Bernhard, Professor of Chemistry, State Normal School, La Crosse, Wis.
Ueber die Einführung von Acylen in den Benzoylessigaether.

Warren Rufus Smith, Professor and Head of the Department of Chemistry, Lewis Institute, Chicago, Ill.
On the Addition Products of the Aromatic Isocyanides.

1896 Bernard Conrad Hesse, Consulting Chemist, General Chemical Co., New York City.
On Malonic Nitrile and Some of Its Derivatives.

Samuel Ellis Swartz, Professor of Chemistry and Physics, Fairmount College, Wichita, Kan.
The Action of Sodium Ethylate on Amide Bromides.

1897 James Bert Garner, Professor and Head of the Department of Chemical Engineering, University of Pittsburgh, and Director of Research, Hope Natural Gas Co., Pittsburgh, Pa.
Condensations with Benzoin by Means of Sodium Ethylate.

1897 Lauder William Jones, Research Professor of Organic Chemistry, Princeton University, Princeton, N.J.
On Salts of Nitroparaffine and Acylated Derivatives of Hydroxylamine.

1898 Frank Burnett Dains, Professor of Chemistry, University of Kansas, Lawrence, Kan.
On the Isourea Ethers and Other Derivatives of Ureas.

Otto Folin, Hamilton Kuhn Professor of Biological Chemistry, Harvard Medical School, Boston, Mass.
On Urethanes.

Elizabeth Jeffreys, Professor of Chemistry, Pritchett College, Glasgow, Mo.
On Undecylamine and Pentadecylamine and the Preparation of the Higher Amines of the Aliphatic Series.

Herbert Newby McCoy, Vice-President, Linsay Light Co., Chicago, Ill.
On the Hydrochlorides of Carbo-phenylimido Derivatives.

1899 John Charles Hessler, Professor and Head of the Department of Chemistry, Knox College, Galesburg, Ill.
On Alkyl Malonic Nitriles and Their Derivatives.

William McPherson, Professor and Head of the Department of Chemistry and Dean of the Graduate School, Ohio State University, Columbus, Ohio.
On the Nature of the Oxyazo Compounds.

James Harvey Ransom, Professor and Head of the Department of Chemistry, James Millikin University, Decatur, Ill.
On the Molecular Rearrangement of o-Aminophenyl Ethyl Carbonate to o-Oxyphenylurethane.

1900 Henry Chalmbers Biddle, Chemist, Berkeley, Cal.
Ueber Derivate des Isuretins, der Formhydroxamsäure und ihre Beziehungen zur Knallsäure.

1901 Ralph Harper McKee, Professor of Chemical Engineering, Columbia University, New York, N.Y., and Director of Research Laboratory, Tennessee Copper Co., Ridgewood, N.J.
On the Oxygen Ethers of the Ureas: Methyl- and Ethylisourea.

1902 Solomon Farley Acree, Research Chemist, National Wood Chemical Association, Syracuse, N.Y.
On Sodium Phenyl and the Action of Sodium on Ketones.

Wallace Appleton Beatty, Research Chemist, Beechnut Packing Co., Brooklyn, N.Y.
The Action of Carbon Monoxide on Sodium Alcoholates Alone and in the Presence of Salts of Fatty Acids.

Eugene Paul Schoch, Professor and Chairman of the School of Chemistry and Chairman of the School of Chemical Engineering, University of Texas, Austin, Tex.
The Red and the Yellow Mercuric Oxides and the Mercuric Oxychlorides.

Edwin Emery Slosson, Editor, *Scientific News Service*, Washington, D.C.
On Acylhalogenamine Derivatives and the Beckmann Rearrangement.

1903 Henry Tabor Upson, President and Treasurer, Pease Oil Co., Buffalo, N.Y.
The Molecular Rearrangement of Aminophenylalkyl Carbonates.

1904 Maxwell Adams, Professor of Chemistry, University of Nevada, Reno, Nev.
On Some Hydroxylamine Compounds.

1904 Raymond Foss Bacon, Consulting Chemist, New York, N.Y.
On the Reactions of Sodium Benzhydrol.

William McAfee Bruce, Brinkley, Ark.
On the Oxygen Ethers of Urea.

Nellie Esther Goldthwaite, Associate Professor of Home Economics, Colorado State Agricultural College, Fort Collins, Colo.
On Substituted Benxhydrol Derivatives and Bromcyanacetic Ether.

Oswin W. Willcox, Chief Chemist and Superintendent, Aetna Explosives Co., Mount Union, Pa.
On the Reactions of Ethyl Chlorsulphonate.

1905 William Lloyd Evans, Professor of Chemistry, Ohio State University, Columbus, Ohio.
On the Behavior of Benzoyl Carbinol toward Alkalies and Oxidizing Agents.

William McCracken, Professor of Natural Sciences, State Normal School, Kalamazoo, Mich.
Studies in Catalysis. V. The Catalysis of Imidoesters.

Herman I. Schlesinger, Associate Professor of Chemistry, University of Chicago, Chicago, Ill.
Studies in Catalysis. VI. The Catalysis of Imidoesters.

1906 Roy Hutchinson Brownlee, Consulting Chemist, Pittsburgh, Pa.
On Precipitated Sulphur.

Charles M. Carson, Professor and Head of the Department of Chemistry, Houghton School of Mines, Houghton, Mich.
On Amorphous Sulphur: Further Study of the Two Forms of Liquid Sulphur as Dynamic Isomers.

Henry Max Goettsch, Assistant Professor of Technical Chemistry, University of Cincinnati, Cincinati, Ohio.
The Absorption Coefficients of Uranium Compounds.

Willis Stose Hilpert, Vice-President, The Miner Laboratories, Chicago, Ill.
Stereoisomeric Chlorimido Acid Esters.

James Wright Lawrie, Research Chemist, E. I. du Pont de Nemours and Co., Wilmington, Del.
The Chemistry of the Acetylidene Compounds.

Andrew Fridley McLeod, Professor of Physical Chemistry, William and Mary College, Williamsburg, Va.
On Aldol, Pentaerythrose, and the Action of Copper Acetate on the Hexoses.

1907 †Edith Ethel Barnard.
The Catalysis of Imidoesters as Affected by the Presence of Non-Electrolytes and Electrolytes.

Katherine Blunt, Associate Professor of Food Chemistry and Chairman of the Department of Home Economics, University of Chicago, Chicago, Ill.
The Formation of Amidines.

Willey Denis, Assistant Professor of Chemistry, Tulane University, New Orleans, La.
On the Behavior of Various Aldehydes, Ketones, and Alcohols toward Oxidizing Agents.

Robert Anderson Hall, Research Chemist, Colgate and Co., New York, N.Y.
The Action of Ammonia on Isourea Esters.

† Deceased.

1907 Louis Allen Higley, Professor of Chemistry, New Mexico College of Agriculture and Mechanical Arts, State College, N.M.
On the Behavior of Sodium and Sodium Alcoholates toward Various Esters.

William Horace Ross, Research Chemist, Bureau of Soils, Department of Agriculture, Washington, D.C.
On the Relation between the Radioactivity and the Composition of Thorium and Uranium Minerals.

Louis A. Test, Professor of General Chemistry, Purdue University, Lafayette, Ind.
The Rearrangement of o-Amino-Phenyl Esters.

1908 George Cromwell Ashman, Professor of Chemistry, Bradley Institute, Peoria, Ill.
Studies in Radioactivity.

1909 Ernest Anderson, Professor of Chemistry, University of Nebraska, Lincoln, Neb.
The Action of Fehling's Solution on *d*-Galactose.

William Weldon Hickman, Professor of Chemistry, Assuit College, Assuit, Egypt.
The Catalysis of Imidoesters.

Winford Lee Lewis, Professor and Head of the Department of Chemistry, Northwestern University, Evanston, Ill.
On the Action of Fehling's Solution on Malt Sugar.

Peter Powell Peterson, Ranch Owner, Idaho Falls, Idaho.
Stereoisomerism of Chlorimido-Ketones.

Lemuel Charles Raiford, Professor of Chemistry, University of Iowa, Iowa City, Iowa.
Chlorimido Quinones.

Herman Augustus Spoehr, Chemical Plant Physiologist, Carnegie Institution, Carmel, Cal.
The Behavior of the Ordinary Hexoses toward Hydrogen Peroxide in the Presence of Alkaline Hydroxides as Well as of Various Iron Salts.

1910 Emma Perry Carr, Professor and Head of the Department of Chemistry, Mount Holyoke College, Mount Holyoke, Mass.
The Aliphatic Imidoesters.

Elbert Edwin Chandler, Professor of Chemistry, Occidental College, Los Angeles, Cal.
Ionization Constants of the Second Hydrogen Ion of Dibasic Acids.

Ira Harris Derby, Consulting Chemist, Republic Creosoting Co., Indianapolis, Ind.
Studies in Catalysis of Imidoesters, IV.

Stewart Joseph Lloyd, Professor and Head of the Department of Chemistry and Metallurgy, University of Alabama, University, Ala.
Studies in Radioactivity.

Alan W. C. Menzies, Professor of Chemistry, Princeton University, Princeton, N.J.
Studies in Vapor-Pressure.

John Colin Moore, Instructor in Chemistry, Tilden Technical High School, Chicago, Ill.
The Action of Water on Acyl Isoureas.

William Cabler Moore, Research Chemist, U.S. Industrial Alcohol Co., Baltimore, Md.
Studies in Organic Amalgams.

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On the Action of Normal Barium Hydroxide on d. Glucose and d. Galactose.

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A Study of Thermostats.

John Foote Norton, Associate Professor of Bacteriology, University of Chicago, Chicago, Ill.
Simultaneous Reactions in Amidine Formation.

Harlan Leo Trumbull, Research Chemist, Goodrich Co., Akron, Ohio.
The Molecular Rearrangement of Acid Chloramides and the Ionization of Their Salts.

Leroy Samuel Weatherby, Professor of Chemistry, University of Southern California, Los Angeles, Cal.
The Salt-Effects of the Nitrates and Sulphonates in the Catalysis of Imidoesters.

Franklin Lorinzo West, Director, School of General Science, Professor of Physics, Utah Agricultural College, and Physicist, Utah Experiment Station, Logan, Utah.
The Physical and Chemical Properties of Organic Amalgams.

1912 Paul David Potter, Chief Chemist, Sprague, Warner & Co., Chicago, Ill.
The Hydrates of Arsenic Pentoxide.

Charles Herman Viol, Chief Chemist, Standard Chemical Co., Pittsburgh, Pa.
The Chemical Properties and Relative Activities of the Radio-Products of Thorium.

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The Thermal Decomposition of the Symmetrical Diaryl-Hydrazines.

John William Edward Glattfeld, Assistant Professor of Chemistry, University of Chicago, Chicago, Ill.
The Oxidation of *d*-Glucose in Alkaline Solution by Air as Well as by Hydrogen Peroxide.

Paul Nicholas Leech, Research Chemist, American Medical Association, Chicago, Ill.
The Molecular Rearrangement of Triaryl Methyl Hydroxylamines; a New Interpretation for the Rearrangement of Ketoximes.

Ethel Mary Terry, Assistant Professor of Chemistry, University of Chicago, Chicago, Ill.
The Velocity Coefficient of Saponification of Ethyl Acetate.

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Studies in Overvoltage.

Arthur Wesley Martin, Superintendent, South Anhwei District, Methodist Church, Tunke, Anhwei, China.
Studies on Solutions in Anhydrous Formic Acid.

Agnes Fay Morgan, Associate Professor of Household Science, University of California, Berkeley, Cal.
I. Viscosities of Various Methyl and Ethyl Imidobenzoates and of the Sodium Salts of Para and Meta Nitrobenzoyl-chloroamides in Moderately Concentrated Aqueous Solutions. II. The Molecular Rearrangement of Some Triaryl Methylchloroamines.

1914 HARRY MORRILL PAINE, Research Chemist, Box 393, Hartsdale, N.Y.
The Effects of Salts on the Solubility of Other Salts: 1. The Solubility Relations of a Very Soluble Bi-univalent Salt. 2. The Ionization of Bi-bivalent Salts.

HARLEY MARTIN PLUM, Chemist, Standard Chemical Co., Pittsburgh, Pa.
The Extraction and Separation of the Radioactive Constituents of Carnotite.

BERT ALLEN STAGNER, Research Chemist, Union Oil Co., San Francisco, Cal.
On the Molecular Rearrangements of Triarylmethyl Hydroxylamines.

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The Action of Alkaline Hydrogen Peroxide on d. Galactose.

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The Addition Compounds of Organic Substances with Sulphuric Acid.

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On the Esters, as well as the Monomolecular β- and γ-Lactones of d-Mannonic and d-Gluconic Acids; On Ortho Bis-d-Galactonic Acid, d-Galactonic γ-Lactone and Its Mono-Hydrate.

EDMUND CHARLES HUMPHERY, Chemist, E. I. du Pont de Nemours Co., Wilmington, Del.
Surface Tension at the Interface between Two Liquids.

TOWNES RANDOLPH LEIGH, Professor and Head of the Department of Chemistry, University of Florida, Gainesville, Fla.
On Chlorimido Esters and Chlorimido Benzil.

EDWIN DANIEL LEMAN, Research Chemist, Radium-Luminous Co., Orange, N.J.
The Relation between the Alpha-Ray Activities and Ranges of Radioactive Substances.

HELEN TREDWAY (Mrs. Evarts A. Graham), c/o Dr. E. A. Graham, Washington University, St. Louis, Mo.
The Thermal Decomposition of Diaryl Hydrazines.

ERNEST DANA WILSON, Director, Commercial Research Dept., George Batten Advertising Co., New York City.
The Structure of Complex Atoms.

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A Study of the Emanation Method of Determining Thorium.

CLYDE COLEMAN, Research Chemist, Ault & Wiborg Co., Cincinnati, Ohio.
Further Studies on the Behavior of the Alkali Metal Formates in (Anhydrous) Formic Acid.

RALPH EDWIN HALL, Research Chemist, Bureau of Mines, Pittsburgh, Pa.
The Periodic System and the Properties of the Elements. The Free Energy of Dilution. The Freezing-Point Lowerings of Some Salts of Various Types of Ionization and of Salt Mixtures.

LAWRENCE MELVIN HENDERSON, Assistant Professor of Physical Chemistry, The University of Minnesota, Minneapolis, Minn.
The Ratio of Mesothorium to Thorium in Minerals.

WILLIAM TUDOR PEARCE, Professor of General Chemistry, North Dakota Agricultural College, Agricultural College, N.D.
Ionization and Solubility Relations of Salts of Higher Types, Intermediate Ions in Solutions of Unibivalent Salts and of Lanthanum Iodate, a Triunivalent Salt. II. Solubilities of Very Soluble Higher Type Salts.

1916 Willard Allen Roberts, Research Chemist, General Electric Company, Harrison, N.J.
Studies on the Cobalt-Ammines.

Stanley Davis Wilson, Assistant Professor of Chemistry, Union Medical College, Peking, China.
The Effect of Added Salts upon the Velocity of Saponification of Ethyl Acetate by Sodium Hydroxide.

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The Spectrum of the Isotopes of the Lead. The Structure of the Bismuth Line $x = 4722$A.

Ralph Lyman Brown, Research Chemist, U.S. Bureau of Mines, Pittsburgh, Pa.
The Molecular Rearrangement of Sym. Di-triphenylmethylhydrazine.

Sidney Marsh Cadwell, Research Chemist, United States Rubber Co., New York, N.Y.
The Beckmann Rearrangement: Determinations of Minute Quantities of Gold.

Earl Claudius Hamilton Davies, Associate Professor of Chemistry, University of West Virginia, Morgantown, W.Va.
The Orientation of Molecules in the Surface of Liquids, the Energy Relations at Surfaces, Solubility, Adsorption, Emulsification, Molecular Association, and the Effects of Acids and Bases on Interfacial Tension.

Adeline Mae De Sale (Mrs. George K. Link), Instructor in Chemistry, University of Chicago, Chicago, Ill.
The Velocity of Rearrangement of Benzoylazid.

Milton Theodore Hanke, Research Instructor, Sprague Memorial Institute, University of Chicago, Chicago, Ill.
The Oxidation of Maltose in Alkaline Solutions by Hydrogen Peroxide and by Air. The Preparation and Study of Maltobionic Acid.

Frank Hynes Reed, Supervisor of Industrial Research, Butterworth Judson Corporation, Newark Transfer, N.J.
Studies in Conductivity. (A) Some Common Errors in the Determination of the Conductivity of Solutions. (B) The Behavior of Mixtures of Two Salts Containing a Common Ion, in Anhydrous Formic Acid Solutions.

James Kuhn Senior, Research Chemist, Fries and Fries, Cincinnati, Ohio.
Molecular Rearrangements in the Triarylmethylazide and Triarylmethylhydrazine Series.

Herbert Johnson Smith, Associate Professor of Chemistry, Mississippi Agricultural and Mechanical College, Agricultural College, Miss.
Solubility Products of Carbonates.

Ralph Kempton Strong, Professor and Head of the Department of Chemistry, Reed College, Portland, Ore.
Mesothorium-One and Radium; Their Isotopism and Enrichment.

William De Garmo Turner, Professor and Head of the Department of Chemistry, School of Mines, University of Missouri, Rolla, Mo.
The Diffusion of Gases and the Density of Chlorine. A Search for Possible Isotypes of Chlorine.

1918 Denton Jacobs Brown, Associate Professor of Chemistry, University of Nebraska, Lincoln, Neb.
The Velocity of Decomposition of Benzoyl Peroxide.

1918 Frank Emerson Brown, Assistant Professor of Chemistry, Iowa State College, Ames, Iowa.
1. The Structure of the Surfaces of Liquids and Solubility as Related to the Work Done by the Attraction of Two Liquid Surfaces on Each Other. 2. A Standardization of the Method for the Determination of Surface Tension or Free Surface Energy by the Drop-Weight Method. 3. A Simple Apparatus for the Determination of Surface Tension.

Elmer Newman Bunting, Research Associate in Ceramics, University of Illinois, Champaign, Ill.
Transport Numbers of Potassium, Sodium, and Calcium Formates in Anhydrous Formic Acid.

George Lindenberg Clark, National Research Fellow, Harvard University, Cambridge, Mass.
1. The Structure of the Surfaces of Liquids. 2. Secondary Valence and Werner's Coördination Number.

Wilby T. Gooch, Professor of Chemistry, Baylor University, Waco, Tex.
1. Effect of Light on the Velocity of Saponification of Ethyl Acetate. 2. The Velocity Coefficient of the Saponification of Methyl Acetate

Homer Henry Helmick, Bank, Denver, Colo.
A New Method for the Determination of Thorium in Monazite Sand.

Herbert Hiram King, Professor and Head of the Department of Chemistry, Kansas State Agricultural College, Manhattan, Kan.
1. The Structure of Liquids: Adsorption at Liquid—Liquid Interfaces and the Partition of a Solute between Two Liquids. 2. The Structure of Liquids: Adsorption, Solubility and the Double Electric Layer.

Raymond David Mullinix, Professor of Chemistry, Rockford College, Rockford, Ill.
Potassium Permanganate. Studies in Conductivity IV.

Ralph Emory Nelson, Assistant Professor of Chemistry, Purdue University, Lafayette, Ind.
The Coefficient of the Velocity of the Reaction between Sodium Hydroxide and Ethyl Acetate.

Stephen Popoff, Instructor in Chemistry, Iowa State University, Iowa City, Iowa.
Studies of Manganates and Permanganates. I. The Course of the Action between Manganese Dioxide, Potassium Hydroxide and Oxygen, and the Manufacture of Potassium Permanganate.

Edward Noel Roberts, Research Chemist, U.S. Industrial Alcohol Co., Curtis Bay, Baltimore, Md.
Velocity of Saponification of Ethyl Formate.

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The Effect of Electric Currents in Attempts to Induce Molecular Rearrangements.

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I. Symmetrical Tetrapropylethane. II. Reduction of Nitrotriphenylamine.

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The Adsorption of Benzene Derivatives on the Surface of Water. The Work Done by the Attraction between a Mercury Surface and the Surface of an Organic Liquid.

1919 MORRIS SELIG KHARASCH, National Research Fellow in Chemistry, University of Chicago, Chicago, Ill.
Colors of the Second Order. Mercuri-Organic Derivatives.

GEORGE ELMER MILLER, Research Chemist, The Upjohn Co., Kalamazoo, Mich.
Preparation of Pure Cyanogen Chloride; Preparation and Study of of d- and l-Beta-Gamma-Dioxybutyric Acid.

CHARLES H. MILLIGAN, Research Chemist, Ault and Wiborg Co, Cincinnati, Ohio.
The Preparation of dl-P-Methyl-Isopropyl Methyl-Phenyl Hydrazine. The Isolation of Pure d-P-Methyl-Isopropyl Methyl-Phenyl Aniline.

LATHROP EMERSON ROBERTS, U.S. Bureau of Mines, Berkeley, Cal.
A Study of Phase Boundaries.

HENRY JOHN ROSSBACHER, Chemist, Western Electric Company, Chicago, Ill.
M-Tolyl-Ethyl-Barbituric Acid.

KARL THEODOR STEIK, Associate Professor of Chemistry, University of Florida, Gainesville, Fla.
The Effect of Alkali upon Portland Cement.

1920 STEWARD BASTERFIELD, Assistant Professor of Chemistry, University of Saskatchewan, Saskatoon, Sask., Canada.
Derivatives of Isourea and Their Pharmacological Action.

YING CHANG CHENG, Assistant Professor of Chemistry, National University, Peking, China.
Cohesion, Adhesion, Tensile Strength, Tensile Energy, Negative Surface Energy, Interfacial Tension, and Molecular Attraction.

AMANDO CLEMENTE, University of the Philippines, Manila, P.I.
The Relation between Pore Size and Adsorption in Charcoal.

FRANK LOUIS DEBEUKELAER, Research Chemist, Swift and Co., Chicago, Ill.
Derivatives of Phenylethylacetic Acid and of Phenyldiethylacetic Acid.

DWIGHT TARBELL EWING, Professor of Chemistry, Michigan State Agricultural College, East Lansing, Mich.
I. The Densities and Adsorption and Desorption Properties of Gas Mask Charcoals. II. The Effects of Acids and Bases on the Surface Energy of β-β-Dichlorethyl Sulphide ("Mustard Gas").

WARREN WALTER EWING, Assistant Professor of Physical Chemistry, Lehigh University, Bethlehem, Pa.
The Attraction of Mercury for Other Liquids.

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I. Nitrotriphenylamines. II. The Oxidation of Diaminophenolos.

MARY MEDA RISING, Instructor in Chemistry, University of Chicago, Chicago, Ill.
I. The Preparation of Phenylethylbarbituric Acid. II. The Preparation of Para-Ureido-Phenylacetylurea, and Related Compounds. III. An Attempt to Filter the Enzymes of Milk.

JOHN EDWARD SCHOTT, Assistant Professor of Chemistry, Pennsylvania State College, State College, Pa.
I. Oxidation of Benzamide. II. Derivatives of Phenylethylbarbituric Acid.

HERMAN VANCE TARTAR, Assistant Professor of Chemistry, University of Washington, Seattle, Wash.
The Constitution of Murexide and the Theory of Dyes.

1921 HENRY LEON COX, Chemist, Beechnut Packing Co., Brooklyn, N.Y.
Some Derivatives of Linolic Acid.

LILLIAN EICHELBERGER, Research Instructor in Chemistry, University o Chicago, Chicago, Ill.
The Transmutation of Maleic to Fumaric Acid.

AARON FELDMAN, 654 Beck St., New York, N.Y.
The Spreading Coefficient: A Study of the Spreading Properties o Some Organic Liquids.

LEO FINKELSTEIN, Research Chemist, U.S. Bureau of Mines, Washing ton, D.C.
I. Determination of Radium in Meteorites by the Emanation. Method. II. Measurement of Ranges of Alpha Particles by a Modified Bragg Apparatus.

AUBREY CHESTER GRUBB, Assistant Professor of Physical Chemistry, University of Saskatchewan, Saskatoon, Sask., Canada.
Chemical Reactions in the Corona.

MARTIN CHARLES EDWARD HANKE, National Research Fellow in Chemistry, University of Chicago, Chicago, Ill.
An Attempt to Prepare a Mercury Derivative of Dioxydiaminoarsenobenzene (Arsphenamine).

ANSON HAYES, Associate Professor of Chemistry, Iowa State College, Ames, Iowa.
Separation of the Element Chlorine into Isotopes.

VESTUS TWIGGS JACKSON, Assistant Professor of Chemistry, Catholic University of America, Washington, D.C.
The Reaction between Potassium Hydroxide, Manganese Dioxide, and Oxygen.

ISADORE MEYER JACOBSOHN, Independent Research in Chemistry, University of Chicago, Chicago, Ill.
Mercuri-organic Derivatives.

ALFRED EDWARD JURIST, Research Chemist, Enterprise Soap Works, Philadelphia, Pa.
A Rearrangement of the Benzilic Acid Type in the Aliphatic Series.

ROBERT STERN LANDAUER, Standard X-Ray Co., Chicago, Ill.
Triatomic Hydrogen.

KATHARINE LUCILLE MCCLUSKEY, St. Xavier Academy, Chicago, Ill., and Independent Research in Chemistry, University of Chicago, Chicago, Ill.
Some New Derivatives of Quinaldine.

CLARENCE JOHN MONROE, Assistant Professor of Chemistry, School of Mines, Rolla, Mo.
On the Relation of the Compressibility of a Liquid and Its Adsorption and Absorption by Charcoal.

ROBERT SANDERSON MULLIKEN, National Research Fellow in Chemistry, University of Chicago, Chicago, Ill.
I. The Separation of Isotopes. Theory of the Resolution of Isotopic Mixtures by Diffusion and Similar Processes; Experimental Separation of Mercury by Evaporation in a Vacuum. II. The Effect of Acids and Bases on Interfacial Tension.

JOSEPH JAROSLAV PELC, Independent Research, University of Chicago, Chicago, Ill.
Molecular Rearrangements in Some Derivatives of Unsaturated Higher Fatty Acids.

921 George Ross Robertson, Instructor in Chemistry, University of California (Southern Branch), Los Angeles, Cal.
Organic Derivatives of Arsenic.

Frank V. Sander, Instructor in Physiological Chemistry, University of Chicago, Chicago, Ill.
Preparation and Resolution of d1–1.3, Dihydroxybutyric Acid.

James Hollingsworth Clemmer Smith, Assistant Professor of Chemistry, Colorado College, Colorado Springs, Colo.
I. Estimation of Sodium Hyposulphite. II. Arsenic Derivatives of Phenylaminoacetic Acid.

Edgar Wertheim, Associate Professor of Chemistry, University of Arkansas, Fayetteville, Ark.
Preparation of dl-p-Secondary Butyl Phenylhydrazine. Resolution of dl-p-Secondary Butyl Aniline.

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